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CORRELATION OF ELONGATION IN PRIMARY, SECONDARY AND TERTIARY AXES OF PINUS STROBUS AND P. RESINOSA

By RAY C. FRIESNER

Studies dealing with elongation in various species of conifers have been published by a number of investigators but, so far as is known to the writer, only one of these has considered the question of correlation of elongation between primary, secondary and tertiary axes. This study is that of Rees (8) dealing with elongation of the leader and five lateral branches in each of two trees of *Picea rubra*. Apparently, elongation began at about the same time in both leader (primary axis) and lateral branches (secondary axes) but ceased earlier in the latter. Approximately 90% of the total elongation in primary axes was completed at the time of cessation of elongation in secondary axes.

Elongation of the primary axis in both *Pinus resinosa* and *P. strobus* has been shown in all published reports to exhibit essentially a "grand-period" type of curve, i. e. growth rate began slowly, then increased rapidly to a maximum from which it declined, with more or less of a final drag, to a midsummer zero point. My earlier work on these species (3) showed 8 modifications of the "grand-period" type of curve but none of these were of sufficient variation to detract from the essential accuracy of the above conclusion. Following the midsummer zero-point small amounts of elongation were recorded at irregular intervals until complete cessation in mid-autumn, but in no case did the post-midsummer-zero elongation exceed in amount the length of the terminal buds. Similar post-zero elongation was recorded by Kienholz (5).

The total time period during which elongation occurred varied in *P. resinosa* from 54 to 123 days with 90% of the elongation occurring in 54-77 days; and in *P. strobus* from 63 to 112 days. Baldwin (1) records 69 days for *P. resinosa* in New York; and for *P. strobus* he found elongation to continue 91 days in Maine, 98 days in Massachusetts, and 91-112 days in New Hampshire. Cook (2) records 54 days as a 5-year average for duration of elongation in *P. resinosa* in New York. Friesner (3) records 63-77 days for both *P. resinosa* and *P. strobus* in Indiana. Kienholz (4, 5) records 105 days for *P.*

resinosa and 98 days for *P. strobus* in New Hampshire, and 123 days for the former species in Connecticut. Marie-Victorin (6) records 92 days for *P. strobus* in Quebec while Moore (7) records 75 days for the same species on Mt. Desert Island, Maine.

METHODS

On March 23, 1942, rust-proof pins were inserted in twigs about 25 mm behind the terminal buds of 30 lateral (secondary) branches on a single tree of *Pinus strobus*. This tree was approximately 15 years old, 12 "whorls" of lateral branches being present. Each lateral branch so prepared was tagged with a linen tag containing a number for future identification, these numbers running consecutively from 1 to 30. Of the lateral branches so prepared 5 were 1 year old; additional groups of 5 were, 2, 3, 4, and 5 years old; 1 was 6 and 2 each were 7 and 8 years old respectively. Unfortunately, the primary axis of this tree was not prepared for measurement until April 27. These are listed in table I.

On the following day, primary, secondary and tertiary axes were similarly prepared on each of two trees of *Pinus resinosa*. Tree No. 1 of this species contained a total of 60 axes used for measurement. Of these, 21 were secondaries ranging from 1 to 5 years old; 31 were 1-year old tertiaries on 3-, 4- or 5-year secondaries; 7 were 2-year tertiaries on 5-year secondaries; and 1 was the leader or primary axis. These are listed in table I. Tree No. 1 was approximately 14 years old, 11 "whorls" being present. Tree No. 2 of this species contained a total of 70 axes used for measurement. Of these, 1 was the leader or primary axis; 18 were secondaries ranging from 1 to 5 years old; 22 were 1-year old tertiaries on 2-, 3-, 4- and 5-year secondaries; 24 were 2-year old tertiaries on 3-, 4- and 5-year secondaries; and 5 were 3-year old tertiaries on 4- and 5-year secondaries. These are also listed in table I. Tree No. 2 was approximately 15 years old, 12 "whorls" of branches being present.

Beginning on April 4 and at intervals of 1, 2 or 3 days thereafter until June 1, elongation of each of the 160 axes above described was measured to the nearest 0.5 mm. After June 1 measurements were made weekly until June 29 at which time the midsummer zero point had been reached or passed by all axes. A final measurement was made for all axes on October 10. All three trees were on a level site near the center of the Butler University Botanical Gardens. The tree of *Pinus strobus* stands about 5 m northwest of a three of *P. sylvestris* of about equal age and size. Tree No. 1 of *P. resinosa* stands about 6 m northwest of *P. strobus* while tree No. 2 of *P. resinosa* stands about 5 m northeast of *P. strobus* and about 5 m east of another (but unused) specimen of *P. resinosa.*

RESULTS

NATURE OF THE ELONGATION CURVES

Figure 1 presents the curves of elongation for each of the types of axes studied. The curves are based upon the average of all of the individual axes of each type. These are also indicated in table I. Curves 1, 10 and 20 represent primary axes and are each based upon single stems. All other curves are for axes of secondary or lesser rank and, except for number 7 (*P. strobus*) and numbers 25 and 29 (*P. resinosa*), are based upon 2 or more branches.

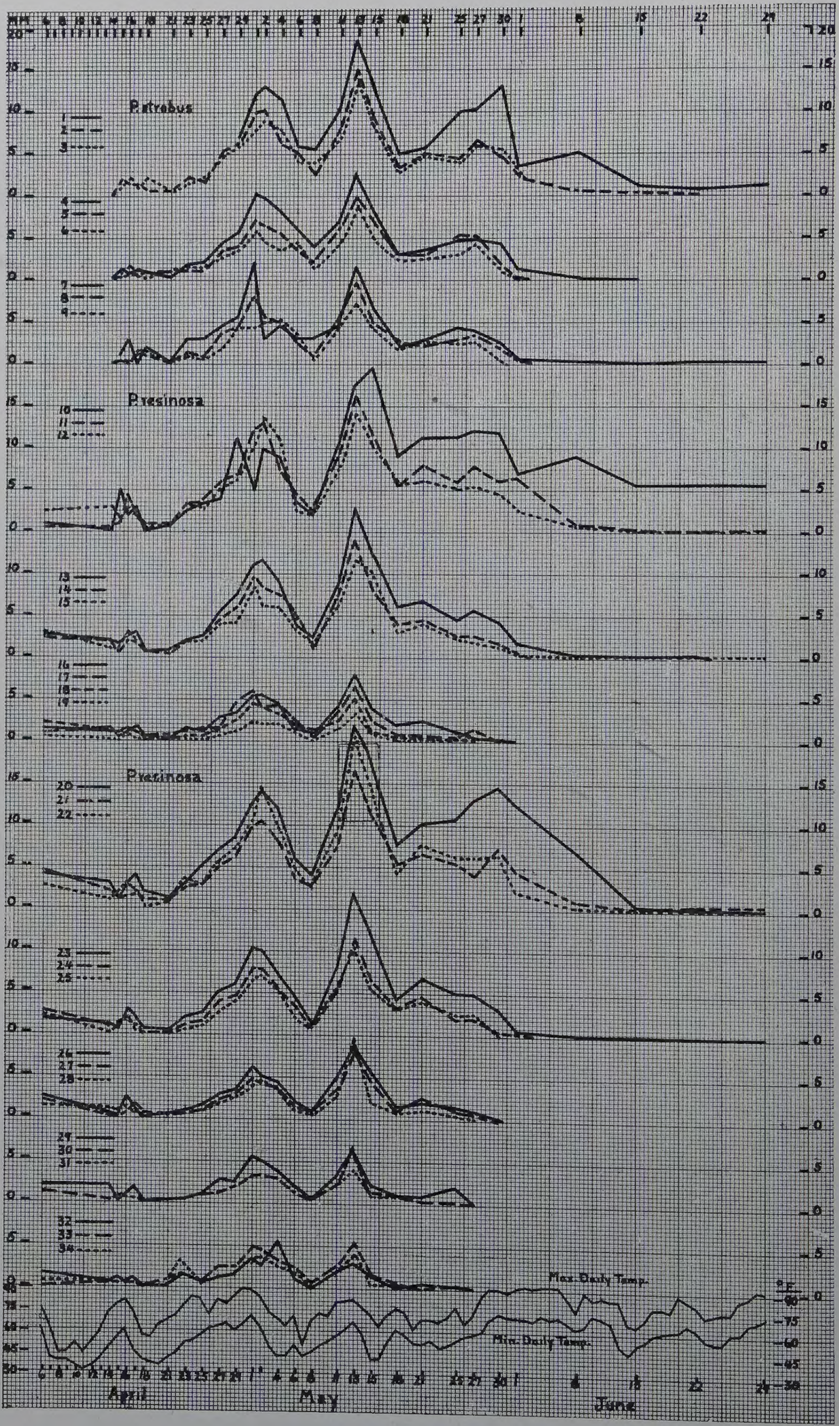
From figure 1 it will be seen that the primary axes (curves 1, 10 and 20) of the three trees exhibit very similar elongation curves and that they do not agree in character with the elongation curves published in any other studies on these species. All previous studies of these species have shown the elongation of the primary axis to exhibit essentially a grand period type of curve while in these three trees each curve shows 3 waves of intensity, which do not have a very close resemblance to the grand-period type of curve.

The secondary and tertiary axes exhibited curves strikingly similar in character and in time of occurrence of the peaks and troughs to those of the primary axes. However, it will be noted that elongation had ceased or was at such a low rate in the secondary and tertiary branches by the time of the third wave of elongation in the primary axes that this third wave is not or only feebly expressed by the branches.

DURATION OF ELONGATION

Initiation of elongation occurred within the limits of a 2-day period in the different axes studied in all parts of the trees. This is in agreement with the results of Rees (8) on *Picea rubra*. Observations were not made at sufficiently short intervals to say whether initiation in all axes of the tree was more nearly simultaneous than within this 2-day period.

From table I and, more graphically, from figure 2, it will be noted that in *Pinus strobus* the primary axis continued elongation for 76 days which was 14 days longer than any of the secondary axes except


MM
20
15
10
5
0
P. strobus
1
2
3
4
5
6
7
8
9
P. resinosa
10
11
12
13
14
15
16
17
18
19
P. resinosa
20
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27
28
29
30
31
32
33
34
Max. Daily Temp.
Min. Daily Temp.
°F.
90
75
60
45
30
6
8
10
12
14
16
18
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23
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27
29
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13
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30
1
8
15
22
29
April
May
June

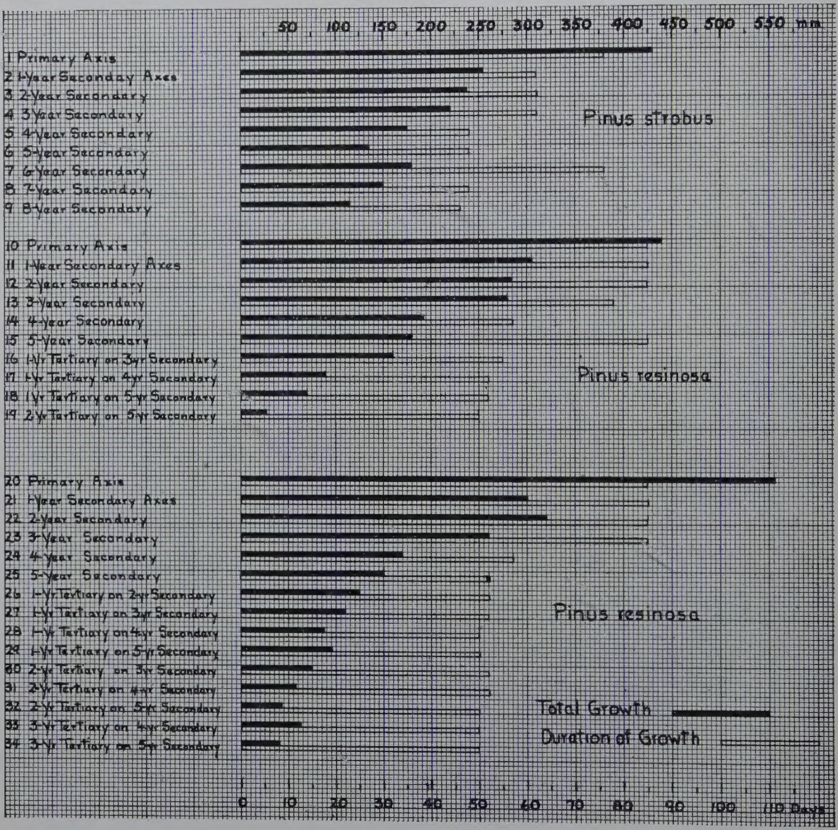
the 6-year secondary which, unfortunately, was the only branch at this "internode." All of the whorls located on the trunk above this one contained 5 branches and those below it each contained 2. The 1-, 2- and 3-year secondaries ceased elongation during the same week having continued for 62 days. The 4-, 5- and 7-year old secondary axes elongated for 48 days and the 8-year secondaries ceased after 46 days. In general it may be said that while elongation begins in all axes at approximately the same time it ceases in the secondary axes successively from the bottom upward, i. e. those farthest from the top cease earlier or the nearer the top the greater the duration of elongation.

In *Pinus resinosa* duration is similar to that occurring in *P. strobus*. In tree No. 1, the 1-, 2- and 5-year secondary axes continued elongating for the same length of time as the primary, i. e. 85 days (table I and figure 2) ; the 3-year secondary axes continued 78 days and the 5-year secondaries were reduced to 57 days. All tertiary axes continued elongation for shorter periods of time than any secondaries and those arising from older secondaries, i. e. lower down on the tree, elongated for shorter periods than those on the younger secondaries. Duration in tertiary axes ranged from 50 to 55 days. In tree No. 2 the results are essentially similar. (See Axes 20-34 in table I and the empty bars in figure 2.)

RATE AND TOTAL AMOUNT OF ELONGATION

Total elongation for each of the different types of axes is given in table 1 and expressed graphically in the empty bars in figure 2. It will be seen that in both species studied, the primary axis added considerably greater length than any other axis of the tree. The secondary axes decreased in total amount of elongation from the top downward and the tertiary axes in every case elongated less than any of the secondaries on the same tree, those on older secondaries elongating less than those on secondaries above them on the tree and older tertiaries less than younger tertiaries even though the younger tertiaries might be on older secondaries.

The most striking difference, however, appears if the solid bars (total amounts of elongation) are compared with the empty bars (duration of elongation) in figure 2. It is apparent that there is much greater difference between the primary, secondary and tertiary axes in amounts than in duration of elongation. The total amounts of elongation of the various axes decrease from the top downward far out of proportion to the decreases in duration. This, in turn, must mean that the daily rate of elongation also decreases rapidly in the different axes arising at levels on the main trunk from the top downward. With both duration and, much more rapidly, the daily rate of elongation, decreasing from the top downward it is readily understood why the total amount of elongation is progressively less on branches arising from successively nearer the base of the tree.



DISCUSSION

Elongation is undoubtedly dependent for initiation upon the presence of some sort of growth-initiating substances elaborated, or at least released, in the terminal buds. The time of release of these substances is probably closely related to external environmental conditions since all terminal meristems begin elongation activity at approximately the same time. Apparently the buds at the tips of all branches regardless of size, age or position on the tree are equally efficient in initiation elongation. Once elongation has begun the coordination of activity between primary, secondary and tertiary axes becomes less and less in proportion as they are more and more removed from each other in point of origin on the main axis.

It may be that the reserves necessary for promotion of cambial activity are drawn more heavily from the lower, older branches or secondary axes, since the cambial cone would necessarily be larger in volume the lower we go on the trunk. This in turn may result in both the earlier cessation of activity and the reduced total elongation in the lateral axes as we proceed downward on the tree.

In cases where the number of secondary axes in any particular whorl is small the duration of elongation appears to be longer than would have been the case had there been a larger number of axes in the same whorl but the total elongation in such single axes is no greater than would have been the case in each axis if as many as 4 or 5 had been present. This is shown in figure 2 for *P. strobus* if we compare axis 7 with axes 3-6.

The significance of the divergence of the elongation curves from the more precise grand-period character usually found in elongating axes in previously published results is unknown. The unusually close correspondence in peaks and troughs of the elongation curves with each other, on the one hand, and with the curves for maximum and minimum daily temperature, on the other hand (fig. 1) may suggest that the temperature changes in these cases were sufficiently great to affect the growth processes. In previous studies the general configuration of the elongation curves does not seem to be materially affected by the temperature changes occurring during the time of major growth activity. The shorter observation intervals (1- and 2-day intervals) used in this study may also account for the closer correspondence between temperature and elongation curves.

SUMMARY

1. Elongation in *Pinus strobus* and *P. resinosa* began at approximately the same time in all of the axes studied regardless of position in the contour of the tree.

2. The primary axis exhibited a greater total elongation and a higher daily rate of elongation than any secondary or tertiary axis, in each of the 3 trees studied.

3. Secondary axes exhibited successively shorter total elongation

and slower daily rate from the topmost whorl of branches downward.

4. Tertiary axes showed shorter total elongation and slower daily rate than secondary axes and those on older secondaries were less than those on younger secondaries.

5. Older tertiary axes elongated less than younger tertiaries even when the former were on secondaries younger than those bearing the latter.

6. In *P. strobus* duration of elongation was longer in the primary than in any of the secondary axes except for a single 6-year secondary which equalled the primary. The secondaries of the upper 3 whorls elongated for a longer period of time than those lower on the tree except for the 6-year secondary just mentioned.

7. In *P. resinosa* the duration of elongation in the upper 2-4 secondaries was equivalent to that of the primary axis but secondaries lower down had shorter periods. Tertiaries showed only slightly shorter periods but progressively slower daily rates of elongation.

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TABLE I

List of axes studied. Numbers in first column on left coincide with those used to identify the curves in figure 1.

No.	Location	Number of Axes	Average Total Amount of Elongation	Average Duration of Elongation
	Pinus strobus			
1	Primary axis	1	428+ mm	76 days
2	1-year secondary axes	5	253	62
3	2-year secondary axes	5	235	62
4	3-year secondary axes	5	222	62
5	4-year secondary axes	5	176	48

TABLE I—(Continued)

List of axes studied. Numbers in first column on left coincide with those used to identify the curves in figure 1.

No.	Location	Number of Axes	Average Total Amount of Elongation	Average Duration of Elongation
6	5-year secondary axes	5	135	48
7	6-year secondary axis	1	179	76
8	7-year secondary axes	2	151	48
9	8-year secondary axes	2	115	46
	Pinus resinosa Tree No. 1			
10	Primary axis	1	441	85
11	1-year secondary axes	5	304	85
12	2-year secondary axes	4	287	85
13	3-year secondary axes	5	283	78
14	4-year secondary axes	3	188	57
15	5-year secondary axes	4	180	85
16	1-year tertiary on 3-year secondary axes	14	157	55
17	1-year tertiary on 4-year secondary axes	7	88	52
18	1-year tertiary on 5-year secondary axes	10	68	52
19	2-year tertiary on 5-year secondary axes	7	27	50
	Pinus resinosa Tree No. 2			
20	Primary axis	1	554	85
21	1-year secondary axes	5	300	85
22	2-year secondary axes	4	320	85
23	3-year secondary axes	4	265	85
24	4-year secondary axes	4	171	57
25	5-year secondary axis	1	150	52
26	1-year tertiary on 2-year secondary axes	5	123	52
27	1-year tertiary on 3-year secondary axes	9	108	52
28	1-year tertiary on 4-year secondary axes	7	87	50
29	1-year tertiary on 5-year secondary axis	1	93	50
30	2-year tertiary on 3-year secondary axes	9	68	52
31	2-year tertiary on 4-year secondary axes	13	54	52
32	2-year tertiary on 5-year secondary axes	2	42	50
33	3-year tertiary on 4-year secondary axes	2	61.5	50
34	3-year tertiary on 5-year secondary axes	3	42	50

AN ECOLOGICAL SURVEY OF BERKEY WOODS, A REMNANT OF FOREST PRIMEVAL IN KOSCIUSKO COUNTY, INDIANA

By J. E. Potzger and Ray C. Friesner

In July 1942, we published results of a detailed study of Cox Woods, a remnant of forest primeval in Orange county, located in southern Indiana (9). In the present study we place on record quantitatively a relatively undisturbed stand of forest in the northern part of Indiana. The Berkey Woods is located along the Tippecanoe river, 3.5 miles northwest of Warsaw, and in it is found a giant *Juercus macrocarpa* which Deam (3) calls the "biggest tree in Indiana." It is an excellently preserved specimen of bur oak which inspires by its towering height and immense diameter of trunk. The Warsaw, Indiana, Chamber of Commerce published the following description of this veteran oak: height 124 feet, circumference 23.5 feet, diameter 7.5 feet, distance to first limb 61 feet. Our own circumference measurements on November 30, 1942, were 21 feet and 10 inches, 4.5 feet above the base.

The once renowned Eastern deciduous forest, expressed exceptionally well in Indiana, has now vanished as a forest primeval except for a few isolated smaller tracts. Special effort is made by our department of botany to study every comparatively little disturbed stand of this great forest as a permanent record of the sociological factors which operated. We are of the opinion that forest studies are of greater significance if a quantitative report forms the basis of description. Only thus can comparisons be made with other stands, and in this way only can botanists of the future reconstruct the forest primeval.

Tharp (11) describes the northwestern quarter of the state in which the Berkey Woods is located as a slightly uneven plain with a few prominent ridges. Much of the section is "somewhat undulating" and rises only a few feet above the wide flats near Leesburg, Kosciusko county. The fertile loam soil of the area also promises good returns for agriculture.

METHODS

Fifty 100-square-meter quadrats were involved in the quantitative study. A stout cord divided by loops into four ten-meter sections, rolled on a large reel, was used to mark off the quadrats. The loops fitted easily over wooden stakes driven into the ground and thus facilitated a comparatively rapid tabulation of the fifty quadrats. One person laid out the quadrats, another called the species and measured DBH. of stems one inch or above, and a third person tabulated the results. All trees one inch or over in diameter were measured with wooden calipers. DBH. measurements as well as number of stems in the quadrat were recorded. All young trees less than one inch DBH. but at least one meter in height were also counted. It is our opinion that young trees of this size record more accurately the status of reproduction than seedlings, which may not survive the first season.

RESULTS

Thirty woody species constitute the major part of the vegetation complex (table I). These can be divided roughly into 18 species of tall trees, 3 of small trees, 3 of tall shrubs, and 6 of small shrubs. A striking feature is the absence of lianas. The crown cover is controlled primarily by *Acer saccharum* and *Fagus grandifolia* as density, frequency, and basal area well reflect (table I). However, so many other species participate in the arboreal layer that the stand can hardly be called beech-maple. For that reason we favor the mixed mesophytic forest concept of Miss Braun (2). We consider this to be the typical climax for Indiana (9) in the most mesophytic habitat sites. The F. I. of the second layer trees (Ostrya, 54% and Carpinus, 20%) show that this layer is only weakly expressed. While the representation of shrubby species is high, coverage of the stratum is low. Only *Asimina triloba* with a F. I. of 56% and density of 400 stems makes any decided claim on high coverage. Both *Acer saccharum* and *Fagus grandifolia* show excellent reproduction (table I). The Berkey Woods is outstanding by the rather impressive number of very large trees. Just to name the DBH. in inches of a few of these: *Liriodendron* 46, 48, 49; *Fraxinus quadrangulata* 31; *Ulmus thomasi* 48, 49, 44, 36; *Quercus macrocarpa* 32, 33 in addition to the one previously described as the largest tree in Indiana.

DISCUSSION

Papers on forest study—even those designated as ecological surveys, are primarily of two types, viz. (1) descriptive: based on superficial peripheral observations; and (2) diagnostic: based on quantitative and qualitative field data. The first type deals with generalities and can hardly be used in a comparable manner with studies in other localities, hence can never lead to a solution in the understanding of vegetation. Plato says, "If arithmetic, mensuration and weighing be taken from any art that which remains will not be much." This is certainly true of an ecological analysis of the complex Eastern deciduous forest. As we have stressed in previous studies, mere observational studies of a forest is inaccurate in detail. A few large trees may catch the eye, and the observer receives the impression that these species constitute the most important part of the vegetation complex, when in reality they may play only a minor role. Merging phenomena can be appreciated adequately only if quantitative data are available. This is, no doubt, the reason why botanists, in experimental fields where quantitative data back conclusions, frequently feel that the work of the ecologist is vague. It would be of tremendous value to an understanding of forest primeval, before civilized man disturbed it so extensively, if we had quantitative data on at least a few larger tracts. We would no doubt have a better picture of the sociology and the environment which controlled it.

According to Tharp (11) the soil occupied by the Berkey Woods is of a fertile loam type with fine water-holding capacity which carries good moisture conditions through prolonged rainless periods. Very favorable mesophytic habitat conditions are evidently necessary to enable the ultimate climax mixed mesophytic forest to establish and maintain itself in Indiana. Apparently it finds expression in any part of the state where the above-mentioned habitat conditions prevail. In southern Indiana it is found on north-facing slopes (8) and in northern Indiana on the better loam soils.

The number of tree species entering into the forest complex is similar to that of Cox Woods (9), but shrub species are more abundant. *Juglans nigra* and *Liriodendron tulipifera* occupy a less prominent place in the Berkey stand than in the Cox Woods. This may be due to selective cutting. Two large black walnut stumps observed, one 16.5 feet in circumference 3 feet above the base, the other 14 feet, 3 inches, indicate that at least some of the more valuable timber trees were cut. The numerous stems in the small size classes (table I) also reflect some disturbance by man. As Auten (1) and Potzger (7) have found, a mature forest supports less than 300 stems per acre and the Berkey Woods has a considerably higher number. All important components of the crown cover show excellent reproduction, even Fagus has a much greater representation in the young stem group than in many stands of central southern Indiana as reported by Potzger and Friesner (8).

Special attention should be drawn to the important place which *Ulmus thomasi* takes in the large size-classes, and therefore in control of the crown cover. Bog pollen studies clearly indicate that Ulmus is a persistent invader of the forests in post-Pleistocene times but seldom shows aggressive tendencies (4, 5, 6, 10). Its winged seeds facilitate invasion, and its physiological requirements must permit a wide range of temperature suitable for ecesis. *Ulmus thomasi* as a rule is a common floodplain species in most Indiana forests. Its abundance in the Berkey Woods associated there with *Acer saccharum* and Fagus indicates high soil moisture but not lacking aeration, at least not during the growing season. While *Asimina triloba* occupies a similar position in both Cox and Berkey woods its abundance and frequency are lower in the northern stand. Fagus and *Acer saccharum* are without doubt the most important species in the mixed mesophytic forest in Indiana, which is also indicated by the frequent reference to this type as beech-maple. Abundance and frequency figures of table I characterize them, too, as most aggressive in control of the crown cover. One is always impressed with the prolific reproduction of *Acer saccharum* in mesic habitats over its entire range. Table I so graphically pictures the association complex which represents the ultimate climatic climax forest in Indiana under most favorable soil moisture conditions that lengthy discussions are hardly required. A detailed comparison of several stands of forest primeval (mixed mesophytic) still existing in Indiana was given in the study on Cox Woods by Potzger, Friesner and Keller (9).

SUMMARY AND CONCLUSIONS

1. The paper presents an ecological study of Berkey Woods in Kosciusko county, Indiana. It is based on fifty 100-square-meter quadrat tabulations.
2. Special attention was given the sociological factors frequency, density, basal area and expression of various strata in the woody species.
3. Eighteen species of tall trees participate in the crown cover, four in the small tree stratum and eight in the shrub layer.
4. The most important species in the crown cover are *Acer*

saccharum (F. I. 98; 246 stems one inch or above DBH.; basal area 11,411.87 sq. in.), *Fagus grandifolia* (F. I. 78; 89 stems one inch or over DBH.; basal area 6,985.279 sq. in.), *Ulmus thomasi* (F. I. 56; 56 stems one inch or above DBH.; basal area 9,723.82 sq. in.).

5. *Acer saccharum, Fagus grandifolia* and *Ulmus thomasi,* species with highest F. I., show excellent reproduction.

6. The Berkey Woods is a typical mixed mesophytic forest. This is the ultimate climax in Indiana under optimum mesophytic habitat conditions.

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TABLE I

Results of fifty 100-square-meter quadrat study in Berkey Woods.

Species	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30	Total Stems Above 1 in.	F. I.	Total Basal Area in Sq. In.
Acer rubrum	2		1						1	4	7.0686
A. saccharum	250	133	39	31	24	13	6		246	98	11,411.8720
Aesculus glabra	2	2	1	2					5	12	126.4494
Asimina triloba	288	99	3						102	56	158.6608
Carpinus caroliniana	5	21							21	20	22.7766
Carya cordiformis	13	1			1				2	18	101.3166
Celtis occidentalis	18	6	1						7	22	14.1372
Cornus alternifolia	1									2	
Corylus americana	2									2	
Crataegus sp?	1									2	
Dirca palustris	26	3							3	30	
Fagus grandifolia	34	65	3	1	4	7	9		89	78	6,985.2792
Fraxinus americana	7	3	2	1		4	3		13	24	2,710.4154
F. lanceolata	1	1							1	4	.7854
F. quadrangulata		1		1				1	3	6	805.8204
Juglans nigra						1			1	2	283.5294

TABLE I—(Continued)

Results of fifty 100-square-meter quadrat study in Berkey Woods.

Species	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30	Total Stems Above 1 in.	F. I.	Total Basal Area in Sq. In.
Lindera benzoin	1									2	
Liriodendron tulipifera	1	3	1	3	2			3	12	16	6,032.6514
Ostrya virginiana	60	30	1						31	54	140.5866
Prunus serotina	2	1	1	1					3	8	51.1510
Quercus borealis var. maxima		1					1		2	4	661.3068
Q. macrocarpa								2	2	2	1,659.5502
Ribes sp.?	1									2	
Sambucus canadensis	8									2	
Tilia americana	15	10	1		2	1	2		16	14	1,551.9504
Ulmus americana		1		1					2	4	66.7590
U. fulva	83	8	7	1	1				17	32	330.6534
U. thomasi	30	31	14	3	8	2	1	5	64	56	9,723.8228
Viburnum acerifolium	1									2	
Zanthoxylum americanum	1								1	2	

A STUDY OF THE EFFECT OF PLANT OPERATIONS UPON THE BACTERIAL COUNT OF MILK[1]

By Albin N. Smolelis

This study was carried out to determine how the bacterial count of milk is affected by the various operations in a milk plant. Samples were taken at various points throughout the plant during the processing of the milk. The results obtained serve to show where the milk is affected during the various plant operations. The Breed (2) direct microscopic method was used because it enables the investigator to get quickly both a quantitative and a qualitative result. Today this method is accepted as standard and its use is widespread. Nevertheless, objections to results obtained by it have been advanced, and many investigators believe that for research work the plate method should be used.

In 1937 Strynadka and Thornton (8) advanced four objections to the smear method, their summary of objections should be considered, because it is important that the validity of the smear method be established. They maintain that the Breed method is not to be accepted as accurate because. "1. Non-representativeness of the sample of milk being used. 2. The failure of some bacteria to stain. 3. The non-recognition of stained particles as bacteria or foreign matter. 4. The personal factor." These objections do not seem to have a tremendous amount of importance, because the plate method which is advocated by the two authors also has numerous failings and shortcomings. No one can discount either method because of the first objection of the two authors, for neither the plate nor the smear method involves the use of an absolute cross-section sample of milk. In the small sample of milk required by both methods it is hardly possible to get a truly representative sample. The non-recognition of stained particles and the personal factor can be combined into one objection, and a certain amount of practice will enable a microscopist to identify easily the material involved. The personal factor also manifests itself in the plate method, in that the counting of colonies on plates can be made ineffective by the person who is making the counts. As for the failure of the bacteria to stain, Ward (10), in 1937, reached the conclusion that there is no such difficulty. Ward maintains that, "Pasteurization not merely kills most of the bacteria commonly present in large numbers in raw milk, but renders them invisible when stained with methylene blue." This means that the bacteria which do not stain with methylene blue are the dead bacteria, and those which are stained are live organisms, and thus the unstained bacteria are of no importance.

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[1] A portion of a thesis submitted to the Faculty of the Division of Graduate Instruction in partial fulfillment of the requirements for the degree of Master of Science, in the Department of Botany, Butler University.

Hammer (4) points out a few more short comings of the plate method which are not associated with the smear or Breed method. When organisms are grown on nutrient media, there is the possibility of failure to grow because the media are unsuited. The anaerobes will, in all probability, not grow because of the air supply. The time involved in making the dilutions and incubations is a very important factor, and variations occur because of the time involved. Furthermore the plate count does not give a count of individual bacteria, but rather a count of the growing colonies. The colonies might have been started by one organism or by one thousand organisms, and this is a very important part of the data when the results are given as number of bacteria per cc of milk.

It is known that milk when freshly drawn from a healthy udder contains practically no bacterial flora, yet by the time it reaches the consumer the bacterial counts range from a few thousand to millions per cc. This contamination or increase in bacterial content is affected between the time the milk leaves the udder and the time it is delivered to the consumer and indicates that a part of the contamination takes place at the dairy plant where the milk is processed. Just where, within the dairy plant, is the question this study has attempted to answer.

HISTORY

In 1929 Leete (7) made a study of the bacterial counts of milk samples taken at various places in the plant. His work was primarily a temperature study and he used the plate count in his work. From Leete's study it is obvious that there is a definite trend of increase and decrease, the question that remains is why this occurs. Leete did not attempt to analyze the causes; he merely made the temperature studies. But this increase in microbial count can be attributed to one or both of two causes: (1) Contamination from equipment, (2) Normal growth and increase of thermophiles and thermoduric bacteria.

Harding (5) in 1940, showed that thermophiles accounted for many high counts; his study was conducted over a period of two years in two different dairy plants. He also maintains that contaminations are due to milk stone, machines, holding techniques and repasteurization.

Lazurus (6) discusses three different organisms which are associated with pasteurized milk contamination. He has found three different rod forms all of which are thermophilic, and all of which are said, "To grow at pasteurization temperatures and indicate poor plant sanitation, length of pasteurization, and repasteurization." Lazurus also claims that organisms which are killed by pasteurization are often found in pasteurized milk, and these are due to improperly cleansed utensils. Hammer (4) agrees with Lazurus and claims that almost all of the equipment at the milk plant is capable of increasing the bacterial count. According to Hammer, coolers and bottle fillers are two of the most important sources of bacteria, second in importance being the piping line and the pumps.

Contamination in milk can be traced to numerous sources, and Bryan (3), in 1938, developed a key for the identification of milk flora based on the morphology of milk micro-organisms. In this key he indicates which forms are associated with the various causes. This key simplifies the study of the results obtained and is, therefore, included here.

Shape and Type of Organism		Probable Cause
Rods	Short paired (scattered, clumps or in chains)	Utensils wet, unclean surfaces, especially milking machines.
	Short thick Long thick (scattered, clumps or in chains) Long thin Short thin	Dirty cows or barn, manure, dust, wet milking flanks, dirt.
	Very high counts (with high temperatures)	Poor cooling.
Cocci	Short chains (two to five elements)	Poor cooling.
	Clumps or singles (staphylococci)	Utensils, scum accumulations in open crevices or open seams.

	Tetrads (scattered or clumps)	Dirty cows or barn.
	Streptococci (more than 6 elements)	Streptococcus mastitis.
	Various types scattered throughout (unsanitary in every respect)	Poor production.
Mold	(Spores or mycelium)	Dust in barn or milk-house.
Cells	Polymorphonuclear Lymphocyte Epithelial	1. Milk used too soon after freshening. 2. Milk used too long at end of lactation period. 3. Injury to the udder (traumatic). 4. Mastitis if streptococci are found in unincubated or incubated samples.

The significance of the presence of body cells in milk was not studied in great detail in this paper, but of interest is the material found by other investigators. Hammer (4) maintains that body cells are normally found in milk and that these come from the linings of the milk ducts, milk cistern, teat canal, teat and udder surfaces. He further states that the significance of these is limited, in that various investigators have not come to any definite conclusions regarding the relationship of body cells to the quality of the milk. The variations in counts of what seems to be normal milk have done much to limit the use of the number of body cells as a criterion for the determination of quality milk. The only definite conclusion reached by the investigations carried out, is that a high body cell count, when associated with large numbers of streptococci, is a definite indication of an udder infection, mastitis. From Hammer's discussion it seems safe to say that an average body cell count is about 300,000 cells per cc of milk.

PROCEDURE

One day each week over a period of five months two sets of milk samples were obtained at a dairy in Indianapolis, Indiana. The first set was taken early in the morning and the second set was obtained about the middle of the morning. The samples were taken from seven places in the plant. The locations of sampling were: (1) The raw milk storage tank, (2) Pre-heater, (3) Clarifier, (4) Pasteurizing tank after pasteurization, (5) Cooler, (6) Bottling machine, (7) Bottle.

As soon as the milk was brought into the plant, it was weighed and pumped into a large raw milk storage tank, which was the source of the first sample. The milk was then pumped into a pre-heater; sample number 2 was taken from a pipe line which led from the preheater to the clarifier. After the milk left the clarifier another sample was taken, but this sample was taken out of the pasteurizing tank before pasteurization was started, because the pipe line from the clarifier to the pasteurizing tank was a closed unit. After milk was pasteurized at a temperature of 63° C. for 30 minutes, another sample was taken directly from the bottom of the trough of the milk cooler. The next sample came from the bottling machine, while the final sample was taken from a freshly filled and capped bottle. In this way it was possible to follow the same batch of milk through the complete process, and the evolution of the bacterial number was then observed.

The samples were processed according to the directions given by Breed (2) and Standard Methods for the Examination of Dairy Products (1). The samples were taken with a platinum wire loop which was standardized to deliver 0.01 cc of milk. The milk was put on a clean slide and spread over an area of one square cm and then allowed to dry at room temperature. After the samples were brought back to the laboratory, they were first immersed in xylol to remove the fat, allowed to dry, and then put into 95% alcohol to be fixed. The xylol immersion and the alcohol fixation each took about 5 minutes. The slides were then stained in an aqueous-alcoholic solution of methylene blue. The slides were observed with a 1.8 mm oil immersion lens and a 12.5 x ocular, the diameter of the field was 0.146 mm and made visible 1/600,000 cc of the milk per field.

RESULTS

The results obtained were counts of 30 fields of each smear. Each of these 30 fields, being 0.146 mm in diameter, gave a total of 1/20,000 (.00005) cc of milk for a total of 30 fields. The units and organisms counted were: body cells, diplococci, short streptococci, or those with no more than six elements, long streptococci, or those with more than six elements, staphylococci, isolated cocci, isolated rods, rods in clumps and mold fragments. From these individual counts the following figures were obtained: number of bacteria per 30 fields, number of groups per 30 fields, and average number of bacteria per group.

In order that the results be clearly interpreted it is necessary to list here the method used in determining the groups and numbers of baacteria. Diplococci were listed as two individual organisms and as one group of organisms. The streptococci were listed as were the diplococci, the number of elements composing the chain being listed among the number of bacteria counted and the individual chains being listed as groups. Likewise, staphylococci were counted both as individuals and as groups as were also the rods in clumps. Each isolated rod and isolated coccus was designated as an individual organism and as a group.

In Table I, the results are summarized to show the average counts, by month, of the body cells and organisms for each of the seven places in the milk plant. The average for the whole five months during which the experiment was conducted is also given. Figures for six sets of samples, hereafter known as the "X" samples, are omitted from both the monthly and the five-month averages of the "normal" samples. The milk for these six sets had been placed in the raw milk storage tank the day before it was processed. Since the tank was not refrigerated, the bacterial counts from these milk samples were much higher than in the other samples taken. The average bacterial counts for the six high-count samples are listed separately in the table.

To analyze the data which has been accumlated in this study, another chart has been made which shows the averages of all of the counts, including the "X" samples. The counts of each smear were averaged and the percentage increase or decrease from the count for the preceding step was calculated.

Average number of Bacteria per 30 fields (.00005 cc).

		Step by step change	Accumulated change
1. Storage tank	486.1		
2. Pre-heater	423.2	12.9% decrease	40.3% decrease
3. Clarifier	458.0	7.6% increase	
4. Pasteurizer	289.8	36.8% decrease	
5. Cooler	303.7	4.6% increase	26.2% increase
6. Bottling machine	269.3	11.3% decrease	
7. Bottles	365.7	27.1% increase	
Total percentage of decrease		26.8%	

Average number of Groups per 30 fields.

1. Storage tank	228.1		
2. Pre-heater	203.5	10.8% decrease	46.0% decrease
3. Clarifier	290.4	29.9% increase	
4. Pasteurizer	122.3	57.8% decrease	

5. Cooler	130.9	6.6% increase	31.7% increase
6. Bottling machine	112.2	14.3% decrease	
7. Bottles	161.0	30.2% increase	
Total percentage of decrease		29.3%	

DISCUSSION

A very large number of bacteria is found to be present in the milk while it is in the storage tank. This can be explained as being due to handling prior to the time when the milk is brought into the plant. Improper handling on the farm and during shipment can give the milk a very high bacterial count, and that is probably the reason high counts were found here. Also involved is the handling at the plant before the milk reaches the storage tank, and this probably contributes some more to the high numbers. Holding of any sort in the dairy plant also is not advisable and always increases the number of bacteria present. The samples marked "X" all have abnormally high counts, and these high counts can be attributed to the fact that the milk from which these samples were made was kept overnight at room temperature in the storage tank. They had a total bacterial count which averaged twelve times as high as in the normal samples. In order that the number of bacteria be reduced it is imperative that no holding, without refrigeration, be practiced in the storage tank.

After the milk leaves the storage tank it is pumped through the pre-heater. Here the number of bacteria is decreased an average of 22% in the "X" samples where the initial count in the storage tank was high. In the normal samples, it is generally slightly increased, the average increase being 15%. Considering the "X" and the normal samples together, the indications are that no consistent bacterial change is brought about by the pre-heater.

After the milk is pumped through the pre-heater it goes through the clarifier. Here the number of bacteria is increased in the average normal sample by 42% and is decreased in the "X" samples by 16%. This means that the centrifugal clarifier is not capable of decreasing the number of bacteria, but, rather, increases it unless the initial number is high. Body cells in the milk appear to be decreased by the clarifier, on the average about 30-40% in numbers, their larger size probably causing them to be thrown out of the milk. The clarifier appears to increase slightly the number of long and short streptococci and possibly, also, the staphylococci and rod forms.

Upon leaving the clarifier the milk is then pumped into the pasteurizing tanks and kept there for 30 minutes at a temperature of 63° C. It is here, immediately following pasteurization, that the greatest decrease in the number of bacteria is found, for they are decreased an average of 43% in the normal samples and 34% in the "X" samples. Ward (10) maintains that bacteria, killed by pasteurization, are thereby rendered invisible or non-stainable. From this present study, also, it is indicated that a large percentage of the bacteria in milk are rendered invisible by pasteurization. Except for the long and short streptococci in the normal samples, all types of bacteria seem to be reduced in numbers by the pasteurization.

The cooling, following pasteurization, appears to cause no important change in the total number of bacteria nor in any of the types. In the normal samples the average decrease was 8% but this was offset by an average increase in the "X" samples of 19%.

Before the milk reaches the coolers it is held in the pasteurizing tanks and, while it is being held there, the temperature gradually decreases. When more than one pasteurizing tank was in use at this plant, the milk was kept in the tanks for periods of time often approaching one hour after pasteurization. During this holding period the possibilities of increases in bacterial numbers are great. Also to be considered here is the fact that the milk taken for this sample had been pumped to a cooler and subjected to the cooling process. There are three opportunities for the bacteria to multiply, (1) the holding of the milk in the tanks after pasteurization, (2) pumping through long pipe lines and (3) during passage through the cooler. Thus it is possible to see that pasteurization does kill a great many of the bacteria, in fact in this study pasteurization decreased the number of bacteria by as much as 43%. But, after pasteurization took place, conditions again sometimes became such that the numbers of bacteria were increased. To produce a milk low in bacterial count the cooling procedure would have to be revised in such a way as not to present conditions for the growth of bacteria following pasteurization.

After the milk leaves the cooler and goes through the bottling machine another decrease is observed, it being 6% in the normal samples and 26% in the "X." Why this decrease is found, it is impossible to explain, beyond saying that it might be a latent effect of the cooling or pasteurizing. It might be well to note here that a further study of this phase of milk processing should be made, in order that a more complete analysis be presented. However, the fact that increases are shown in some samples and decreases in others would indicate that the bacterial change is insignificant.

After the milk reaches the bottles and is capped another increase in numbers of bacteria is found. It seems evident that the bottles are responsible for a residual contamination, or, to be more explicit, the rinse water left in the bottles after washing possibly has a large number of bacteria, which would account for the increase following bottling. Also involved here is the cap; it might be the source of some bacteria. This coupled with the rinse water might be the reason for the increase in numbers of bacteria immediately following bottling. The average increase in the number of total bacteria in milk in the bottle over the previous number is 8% in normal samples and 69% in the "X" samples. Part of this may merely be an apparent increase due to the settling out of minute air bubbles in the milk, since there is a slight increase, also, in the average number of body cells.

The total percentage of decrease in the average number of bacteria from the beginning to the end of the process is 24.6%, the decrease in the average number of groups is 29.3%. The average decrease from the time the milk is in the storage tank to the time the pasteurization process is complete is 40.3%. Between pasteurization and bottling there is an increase of 20.9%. The increase which follows pasteurization, or rather the increase between pasteurization and bottling is due to the machinery and the handling of the milk. If there were no more handling of the milk following pasteurization, low count milk would be a simpler matter, but the handling and processing following pasteurization offsets, in part, the beneficial effect of pasteurization from the standpoint of numbers of bacteria. Processing appears to have decidedly different effects on high compared to low count samples. These differences are made evident in the following columns.

Average percentage of increase or decrease of total bacterial count for each procedure in the processing of the milk.

	All Samples	Low count "normal" samples	High count "X" samples
Pre-heater	—13	+15	—22
Clarifier	+ 8	+12	—16
Pasteurizer	—37	—43	—34
Cooler	+ 5	— 8	+19
Bottler	—11	— 6	—26
Bottle	+27	+ 8	+69

The effects of processing on the form types of bacteria are probably not as marked as on the total bacterial count. Diplococci, rods and bacterial "groups" behave essentially in the same manner as does the total bacterial count. Streptococci are increased in number in the clarifier, are not reduced in the pasteurizer, but are decreased slightly by the cooler. Staphylococci vary in numbers throughout the processing but, in general, are not changed significantly as the milk moves through the plant. Isolated cocci are increased in number by the pre-heater after which they decrease. Mold fragments were not found in the milk. Due to the predominance of diplococci, the number of bacteria per group remained much the same, being 2.4 in the "normal" samples and 2.1 in the "X" samples.

Body cells were reduced an average of 39% in normal samples and 33% in the "X" samples by the clarifier. Except for another average decrease of 33% by the pre-heater in the high count samples, the body cells were not greatly affected by the other steps in the milk processing.

CONCLUSIONS

1. The effect of each piece of apparatus used at a certain dairy plant was studied, using the Breed (direct microscopic) method.
2. The results for each sampling date, and even as monthly averages, show considerable variation in the number of organisms present in the milk at the seven sampling points in the dairy plant.
3. Processing in general decreases the number of bacteria found in milk about 27% ; the decrease in the number is due primarily to pasteurization.
4. The pre-heater, clarifier, cooler and bottle frequently cause an increase in the number of bacteria in milk.
5. The pre-heater, pasteurizer and particularly the clarifier tend to cause a decrease in the numbers of body cells in milk.
6. Milk with an initial high bacterial count is affected often in an opposite manner from milk with a normal, low initial count.
7. The final bacterial count could be reduced if: (a) Cleaner milk were produced at the farm, and the clarification process at the dairy plant were eliminated; (b) The holding time between the filling of the storage tank and the pre-heating were reduced to a minimum; (c) The holding time between pasteurization and cooling were eliminated; (d) Greater care in the cleaning and rinsing of bottles were exercised.

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TABLE I

Monthly averages of body cells and organisms per .00005 cc for seven locations in the dairy

Location	Body cells	Diplococci	Short Streptococci	Long Streptococci	Staphylococci	Isolated cocci	Isolated rods	Rods in clumps	Mold Fragments	Number of Bacteria	Number of groups	Average number of Bacteria per group
October												
1	63	140	16	8	57	31	14	9	2	275	128	2.2
2	62	230	11	23	56	124	7	3	0	449	255	2.0
3	36	146	30	30	45	61	24	2	0	327	176	2.1
4	30	82	21	12	22	48	7	2	0	202	107	2.2
5	38	88	11	7	41	31	7	8	0	190	90	2.3
6	18	24	7	0	10	10	6	0	0	55	30	2.4
7	31	58	9	13	13	5	5	2	0	99	49	2.0
November												
1	63	132	12	10	51	3	3	3	1	203	74	2.7
2	62	176	12	9	52	1	3	2	0	251	96	2.5
3	45	156	20	16	65	2	3	2	0	251	93	2.2
4	28	134	36	13	134	3	2	0	0	325	84	3.4
5	37	132	22	13	66	3	4	9	0	240	78	2.9
6	29	118	26	14	147	11	2	1	0	319	84	3.8
7	30	146	30	11	144	16	3	2	0	349	105	3.2
December												
1	48	236	12	3	1	3	2	2	0	258	126	2.2
2	59	154	5	9	4	0	0	9	0	180	82	2.2
3	35	158	7	4	9	0	1	0	0	179	82	2.4
4	33	96	9	5	7	0	2	2	0	120	53	2.2
5	34	74	6	12	0	0	1	1	0	92	40	2.4
6	32	86	4	1	5	0	1	0	0	96	45	2.1
7	36	46	9	2	4	0	1	0	0	62	26	2.4
January												
1	95	94	1	3	9	1	0	0	0	109	49	2.3
2	70	156	1	2	0	0	1	0	0	158	79	2.3
3	38	260	5	3	0	0	1	0	0	270	132	2.0
4	43	104	1	2	0	0	0	0	0	107	51	2.0
5	41	90	5	3	17	0	1	0	0	114	48	2.4
6	42	132	2	3	3	0	0	0	0	141	67	2.1
7	41	136	2	16	0	0	0	0	0	154	70	2.2

TABLE I—(Continued)

Monthly averages of body cells and organisms per .00005 cc for seven locations in the dairy

Location	Body cells	Diplococci	Short Streptococci	Long Streptococci	Staphylococci	Isolated cocci	Isolated rods	Rods in clumps	Mold Fragments	Number of Bacteria	Number of groups	Average number of Bacteria per group
February												
1	73	162	1	0	16	1	1	15	0	194	85	2.7
2	60	124	1	3	0	0	1	0	0	128	63	2.1
3	35	676	3	4	25	1	3	23	1	733	346	2.1
4	30	148	5	23	7	0	1	5	0	190	79	2.5
5	34	170	3	16	10	3	0	1	0	203	91	2.1
6	45	154	1	2	13	2	0	0	0	172	81	2.1
7	35	136	2	4	0	0	2	0	0	143	71	2.0
March												
1	55	44	2	0	3	0	0	4	0	54	24	2.2
2	52	72	1	2	3	0	0	1	0	80	36	2.2
3	34	72	2	0	3	0	2	1	0	82	40	2.0
4	25	60	3	5	0	0	0	0	0	68	31	2.2
5	33	80	2	2	6	1	2	1	0	92	44	2.2
6	27	80	2	6	0	0	1	0	0	90	43	2.1
7	32	114	4	3	18	0	1	1	0	139	60	2.3
October-March Averages												
1	66	134	7	4	23	7	3	6	1	182	64	2.4
2	61	152	5	8	19	21	2	3	0	208	102	2.2
3	37	244	11	10	25	11	6	5	0	307	145	2.1
4	32	102	13	10	28	9	2	2	0	169	68	2.4
5	36	106	8	9	23	6	3	3	0	155	65	2.4
6	32	100	7	4	30	4	2	0	0	146	58	2.4
7	34	106	9	8	30	4	2	1	0	158	64	2.4
Averages of "X" Samples												
1	94	2082	5	16	33	2	2	28	0	2168	1051	2.1
2	63	1596	12	22	32	3	8	17	0	1688	817	2.1
3	42	1294	15	28	35	2	6	29	0	1413	671	2.1
4	36	868	13	12	27	1	1	5	0	927	442	2.1
5	35	1010	5	22	63	1	4	1	0	1101	514	2.2
6	35	736	8	24	26	2	1	4	0	811	376	2.2
7	42	1302	11	24	27	0	1	17	0	1381	658	2.1

PLANKTON AND ITS RELATIONSHIP TO CHEMICAL FACTORS AND ENVIRONMENT IN WHITE RIVER CANAL, INDIANAPOLIS, INDIANA[1]

By EUGENE R. HUPP

PURPOSE OF THE INVESTIGATION

A stream or body of water displaying a large population of algae presents a major problem to the water purification department of many inland cities which depend upon surface supplies as their source of water. Such water when used in the purification process of public supplies, has obnoxious tastes and odors which cannot be completely removed by known treatments. The heavy population of algae will also cause filter matting and clogging which is another problem of equal importance.

The water industry would receive a useful tool if it knew when to expect these plankton pulsations, and what their effect would be upon purification treatments. From this point of view, it would be beneficial to know a prerequisite factor for algal growth and changes occurring in the stream during a plankton pulse.

REVIEW OF LITERATURE

Most of the work published to date on algal growth, its requirements and effects, has been with lake waters and not rivers. Forbes and Richardson (4) in their work on the Illinois River show that the plankton increased 69% after the opening of the drainage canal of the Sanitary District of Chicago, January 17, 1900. This increase in plankton was due mainly to the increase of food supply furnished by the Chicago sewage.

Kofoid (7) in his work on the Illinois River, 1894 to 1899, sought a factor to which he might attribute the diatom pulses. Changes in nitrate content yielded no marked correlation either in amount or direction. This was explained by suggesting that the nitrates are far in excess of the demands of diatoms, due to sewage contamination. Diatom pulses occurring throughout the year seemed to preclude the factor of temperature as the immediate cause of the pulse except as it might affect the growth in individual species. The vernal pulse was obtained each year about May 1, at which time the water passed the temperature of 16° C. The average of the recorded surface temperature of 1898 in the river was 14° C. Kofoid found ten pulses in 1898 from March to January. Seven were found on declining floods and but three on rising water, and two of these three appeared during the slow rise of October-November. He concluded that there was a failure to exhibit any periodic rhythm in food matters in solution and suspension in the river water with which these pulses of chlorophyll-bearing organisms might be correlated.

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[1] A portion of a thesis submitted to the Faculty of the Division of Graduate Instruction in partial fulfillment of the requirements for the degree Master of Science, in the Department of Botany, Butler University.

Atkins (1) states that a deficiency of phosphates apparently limits production of fresh water plants, while Juday (6) claims that there is no definite evidence that the soluble phosphorus was a limiting factor in the production of phytoplankton of lake waters of northwestern Wisconsin. An investigation of limestone quarry pools by Wimmer (16) revealed that there was a general correlation between organic nitrogen and the plankton crop, although no correlation was found between soluble phosphorous and plankton.

Working on the Mississippi River, Weibe (15) concluded that the inorganic nitrogen is apparently not a limiting factor for phytoplankton, but soluble phosphorous may be at times. A study of the Hocking River by Roach (14) included light, acidity, current, chemical condition of the water and water temperature. Only the chemical composition and temperature showed variations that corresponded with changes in plankton. Plankton abundance varied directly with temperature. At three stations, the river was polluted with domestic sewage, and the total plankton decreased, while Myxophyceae and Protozoa increased.

Purdy (13) found on the Ohio River that holophytic organisms are certainly dependent upon sunlight for miximum growth. "The presence of large amounts of organic matter such as sewage resulted in numerous animal forms rather than plants, while dissolved inorganic matter resulting from advanced decomposition, favors the presence of plants as the dominating organisms. If the conditions of the stream were stable and the water was clear enough to admit sunlight, a heavy plankton, principally of diatoms, was the usual result, even if the temperature was low."

In a study of the phytoplankton in English lakes, Pearsall (12) found that diatoms follow the maxima of nitrates, phosphates and silica. Asterionella tended to have higher requirements than Tabellaria. Diatoms did not develop in abundance when the silica was below 0.5 and calcium below 3.0 mgm per liter. Green algae occurred when nitrates and phosphates were low. Myxophyceae showed a general correlation with high organic matter.

Work conducted in California by Goudey (5) indicated that there is a direct relationship of plankton multiplication to the ultra-violet radiations in sunshine. The radiations were measured by a constant recording instrument utilizing a photo-electric cell. Maximum algal growth coincided with the period of maximum ultra-violet ray activity.

Much of the literature stresses importance of an abundance of organic matter in the water as a means of producing a rich plankton. The fact is so well known that growers of pond fishes in Europe deliberately manure their ponds to increase the algae as food supply for their fish. The plankton of the Elbe is largely increased by the sewage of Hamburg and Altona poured directly into that stream. While the indications are that sewage pollution will ultimately increase the plankton, there seems to be, however, a general disagreement among the various workers as to definite chemical and physical requirements essential for plankton growth.

LOCATION AND CONDITIONS OF INVESTIGATION

The present study is one covering a period of four years in which algae from the White River canal were studied at one station and several chemical and physical factors of the water were determined in order to detect correlation between algal pulse and chemical and physical deviations.

The work done in this investigation was on water from the west fork of White River at Indianapolis, Indiana. This river receives sewage from the towns and cities upstream. Until recently, cities such as Anderson and Muncie discharged untreated sewage into this river. It is a flashy stream, that is, it fluctuates easily with normal rainfall. During the late summer and periods of low rainfall the stream is low and very sluggish, having many pools. Two of the major pools are formed by dams at Riverwood and Broad Ripple. The Riverwood dam facilitates local power production, while the Board Ripple dam serves the purpose of feeding water to the canal which is owned and maintained by the Indianapolis Water Company for its supply of water. The pooled water back of the Broad Ripple dam flows through the canal headgates and travels about six miles through the canal to the intake of the Indianapolis Water Company. The rate of flow through this canal is governed by means of gates, making it quite variable. Under normal conditions the rate of flow is approximately 1 mile per hour.

The samples for plankton enumeration were collected daily at 1:00 P. M. in the canal at the intake of the Indianapolis Water Company. All samples were worked as soon as they were collected except those collected during the week-end and these were preserved either by 5% formalin, or by cold storage at 6° C. until Monday morning. The cold storage preservation was soon adopted in preference to formalin because many of the motile organisms were distorted by its action.

METHOD OF PLANKTON ENUMERATION

The organisms of an aliquot portion of the collected sample were concentrated by filtering through fine sand in a Sedgwick-Rafter funnel. The sand and the final 10 ml of the sample were then caught in a small beaker which was swirled gently to dislodge adhering organisms. One ml of this concentrated sample was then poured into a Sedgwick-Rafter plankton counting chamber. It was allowed to stand for about 10 minutes before examination, thus permitting most of the organisms to settle to the floor of the chamber.

The counting chamber was then placed on the mechanical stage of the microscope and examined by using a 20X objective and 10X eyepiece. The eyepiece was fitted with a ruled ocular micrometer, the outer boundaries forming a square field which was divided into 100 smaller squares by the rulings. For a representative count of a sample being examined all of the algae in 10 fields were counted. Each field was that area defined by the large square of the ocular micrometer. The 10 fields selected for counting were evenly spaced along the linear axis of the counting chamber from one end to the other. Each organism or coenobe was counted as one unless it was filamentous or elongated and then it was counted once for each of the small squares it spanned. The organisms thus counted were grouped into, Diatomaceae, Chlorophyceae, Cocci, Myxophyceae, Zooplankton, Euglenophyceae, Heterokontae, Chrysophyceae, and any other group which was found to be represented. The predominating genera occuring in each sample were noted but not given a numerical value individually.

The area outlined by the large square of the ocular micrometer was determined. The number of algae per ml of sample was calculated by multiplying the total number of algae counted in the 10 fields, by the factor that is required to bring the area of one field up to 1 cu mm. This was then multiplied by 100 to bring the volume up to 1 cc,, and was then divided by the concentration of the sample.

$$\frac{\text{Count in 10 fields X factor X 100}}{\text{Concentration of sample}} = \text{Algae per ml}$$

The necessity of working as rapidly as possible led to the adoption of the above method in preference to a more exact but longer one.

CHEMICAL ANALYSIS

Chemical analyses of water taken from the same sampling point as that used for plankton enumeration, were taken from the daily record of the Indianapolis Water Company's laboratory. The chemical analyses used in this study were: alkalinity, free carbon dioxide, dissolved oxygen, pH, ammonia, nitrites, nitrates, phosphates and silicates. Bacterial counts made on agar plates incubated at 37° C. for 24 hours, water temperature and rate of river flow were also obtained from the laboratory records. The ammonia, nitrite and nitrate results were in terms of nitrogen.

RELATIONSHIP OF PLANKTON TO CHEMICAL FACTORS

During the years of 1938, '39, '40 and '41, a daily plankton count was made during the algal season which usually extended from April to December, and a weekly count was made during the winter months of 1940 and '41. Graphs were prepared using the daily results and semi-monthly averages of each of the above-mentioned chemical analyses and the plankton count. By preparing graphs such as these for the four years of work, correlation of the chemical results to the total plankton count were noted. Particular attention was given any factor which seemed to deviate from normal immediately preceding a plankton rise.

In the examination and interpretation of these fluctuations the very important factor, rainfall, must be considered. This affects the chemical results and the algal count by dilution, and may affect plankton multiplication by substituting soft water for hard water, as is usually found in their natural environment. It was noted that when a large amount of rainfall occurred, the algae count made a sharp decline which was a simple dilution factor. During the summer and fall when smaller amount of rainfall occurred, there was a marked increase in the algal count which was probably due to flushing of heavily populated algal pools in the stream and on the watershed. In order to determine the amount of flushing that occurred each year, graphs were prepared using the data obtained from the river gauges located on White River at Broad Ripple and east of Nora, Indiana. The data obtained were rates of flow in terms of cubic feet per second.

RESULTS

1938

The daily results of total algae, diatoms, dissolved oxygen, pH, alkalinity, carbon dioxide, hours of sunshine per day, water temperature, and rate of river flow were used for this year. During this year there were four distinct plankton peaks (plate I). The first occurred during the last of April and the first of May, the second during the last of June, the third during the last of August and the fourth during the first part of October. The first and second pulses were composed of approximately 50% diatoms while the remaining organisms were chiefly Chlorophyceae. The third and fourth pulses were mostly diatomaceous, the third being more so than the fourth, which contained many Chlorophyceae and Cocci, which included spheroid cells occurring singly.

During the summer months there were six different periods of fairly heavy rainfall which increased the rate of river flow and affected all chemical analyses. The rate-of-flow curve continued in a straight line between the middle of September and November 20, thus eliminating rainfall as a factor affecting the other curves. During this period the major plankton peak of the season occurred accompanied by an increase of dissolved oxygen and an initial decrease in alkalinity and pH, with both rising during the middle of the pulse. The carbon dioxide remained fairly constant around 3.0 ppm (parts per million), which is not as might be expected. The number of hours of sunshine occurring during each day was also graphed but no definite correlation with plankton was noted.

The graphs representing daily results had many irregularities which were overcome by graphing semi-monthly averages (table I), Thus obtaining a more general curve. These curves lack detail and in many cases they are not in exact correlation with those of the daily

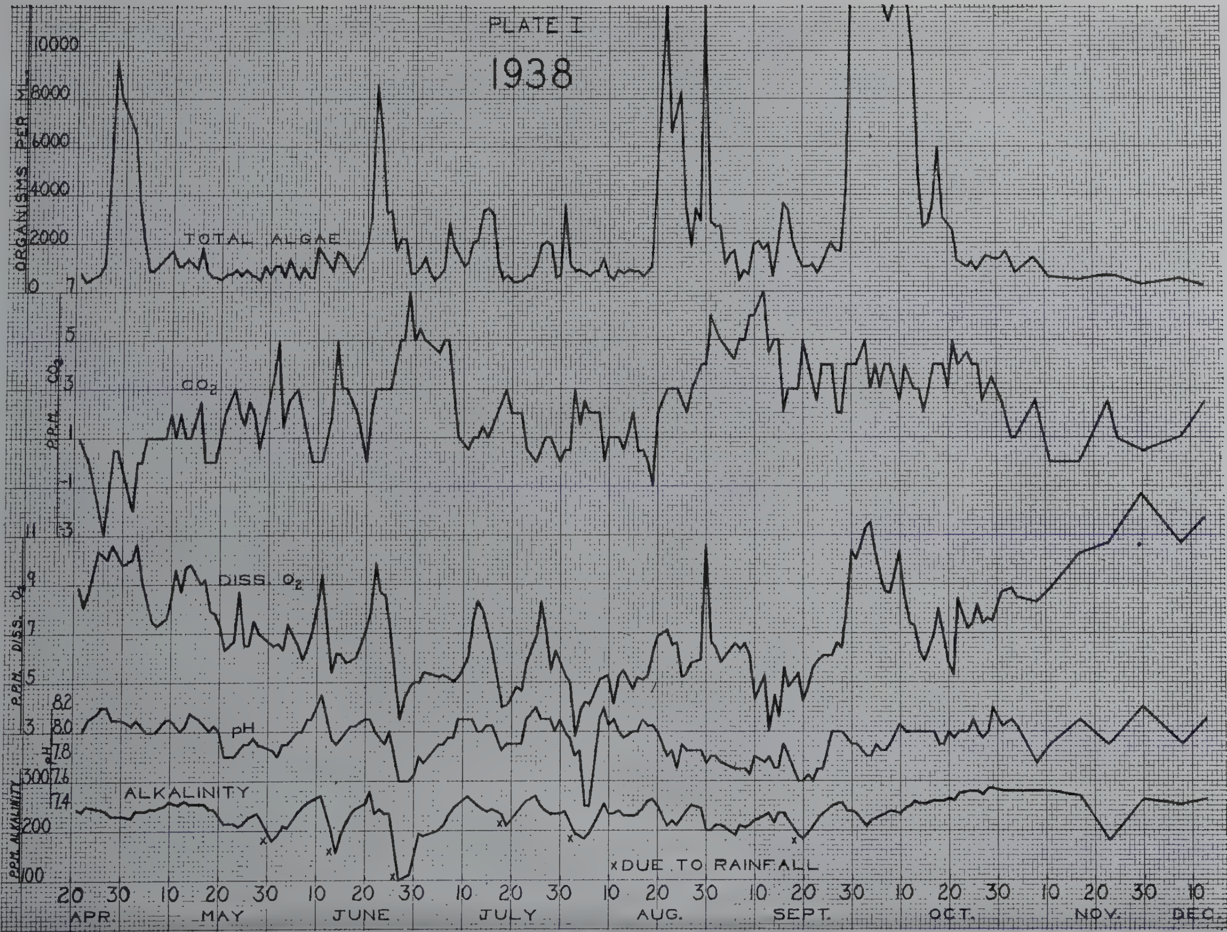


PLATE I

1938

ORGANISMS PER M
10000
8000
6000
4000
2000
0
TOTAL ALGAE
P.P.M. CO₂
5
3
1
-1
-3
CO₂
P.P.M. DISS. O₂
11
9
7
5
3
DISS. O₂
pH
8.2
8.0
7.8
7.6
7.4
pH
P.P.M. ALKALINITY
300
200
100
ALKALINITY
x DUE TO RAINFALL
20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10
APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.

results, but in order to present seasonal fluctuations a graph of this sort is necessary. The semi-monthly averages show that during the August and October plankton pulses there was a corresponding increase of dissolved oxygen while the pH and carbon dioxide did not correlate as well as by using the daily results.

The water temperature had increased to 18° C. before the first vernal plankton pulse occurred. There was no correlation of temperature to plankton population during the warm season. The last plankton peak of the season took place in cooling water that had fallen to 18° C.

1939

During this year the daily results of total algae, diatoms, Chlorophyceae, dissolved oxygen, pH, alkalinity, carbon dioxide, ammonia, water temperature and rate of river flow were used.

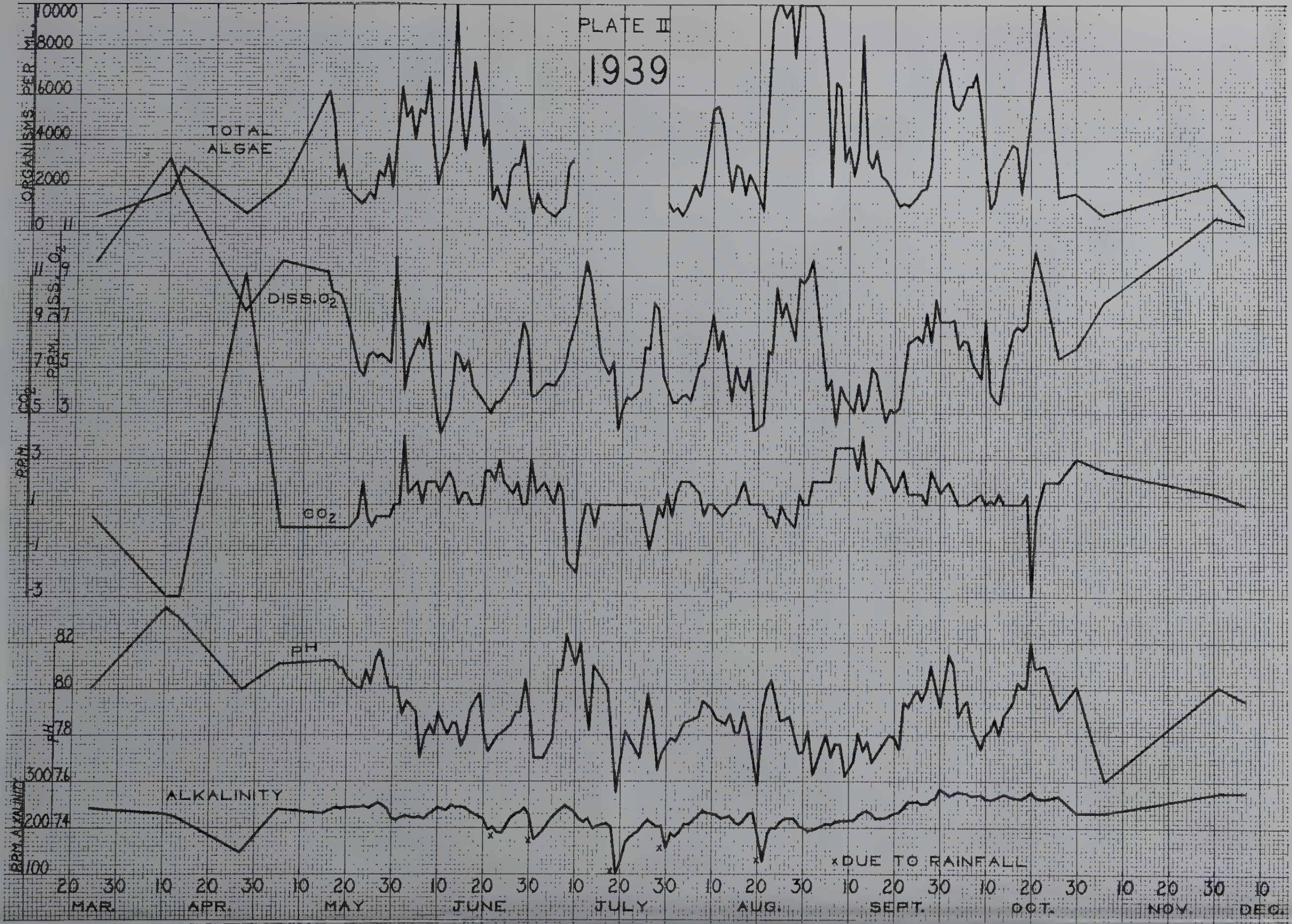
The total plankton count (plate II) reached at least three peaks during the season. The first occurred during the first half of June, the second during the last of August and the first of September and the third during the first part of October. Diatoms seemed to be the predominating organisms during the spring and fall peak periods, but during the mid-summer months, Chlorophyceae were generally the predominating organisms.

By following the graphs representing daily results (plate II), the dissolved oxygen increased with plankton peaks, showing very close correlation. The pH fell as the plankton reached its peak but in many cases it rose as the peak was approached and then fell. The alkalinity curve was affected on five different occasions during the season by rainfall which contributed soft water to the small flashy stream. In general the correlation between alkalinity and plankton was very vague during this year. The carbon dioxide did correlate with plankton in most cases in that it decreased as the plankton increased.

The ammonia seemed to fall during a plankton peak and rise after it, but due to limited results it is difficult to conclude that this is the true picture. As previously mentioned, upstream there are cities such as Anderson and Muncie, which during this time contributed untreated sewage to the stream and any ammonia fluctuations may be due to these sources. On the other hand, if the ammonia fluctuates because of plankton population, the high content following a plankton peak may be due to decaying algal cells while the low content during

PLATE II

1939



a plankton peak may be caused by its consumption by the algal cells during this period of intense activity.

The temperature had reached 10° C. before the first vernal peak which consisted almost entirely of diatoms. By the middle of May the temperature had reached 16° C. and a second diatom peak occurred with only a few Chlorophyceae. The preponderance of Chlorophyceae first appeared on June 1, at which time the water temperature had reached 24° C. The Chlorophyceae then remained as a major class throughout the summer until October 1, when the diatoms were the predominating organisms, and the water temperature had fallen to 18° C.

The graphs composed of the semi-monthly averages (table I) lack detail and magnitude. In order to get a clear picture of the season's results, the graphs of the daily results are necessary (plate II).

1940

The data obtained during this season represented the daily results of total algae, diatoms, dissolved oxygen, pH, alkalinity, carbon dioxide, ammonia, nitrites, phosphates as PO_4, silicates as SiO_2, 37° bacteria per ml, temperature and rate of river flow.

The total algae (plate III) reached four peaks during this season, two of which were major while the other two were of short duration. The first peak, which was a major one, occurred during the middle of May at which time the diatoms also reached their first peak. The second and third pulsations were of short duration and were considered as minor peaks, occurring on June 9 and August 26, respectively. The fourth and last major peak occurred during the last half of October. The organisms composing this flora were practically all Melosira.

At this time attention should be called to a few observations which are irrelevant to the main text of this paper. During the Melosira pulse, numerous upstream and canal surveys were made and each time the Melosira population was greatest in the head waters of the canal. During the flow through the canal from the head waters to the Indianapolis Water Company's intake (approximately 6 miles), 90% of the organisms were lost. The diminishing plankton was directly related to a decrease of dissolved oxygen and an increase of ammonia both of which were probably due to decaying algal cells producing an oxygen demand and liberating ammonia from the algal cells during bacterial assimilation.

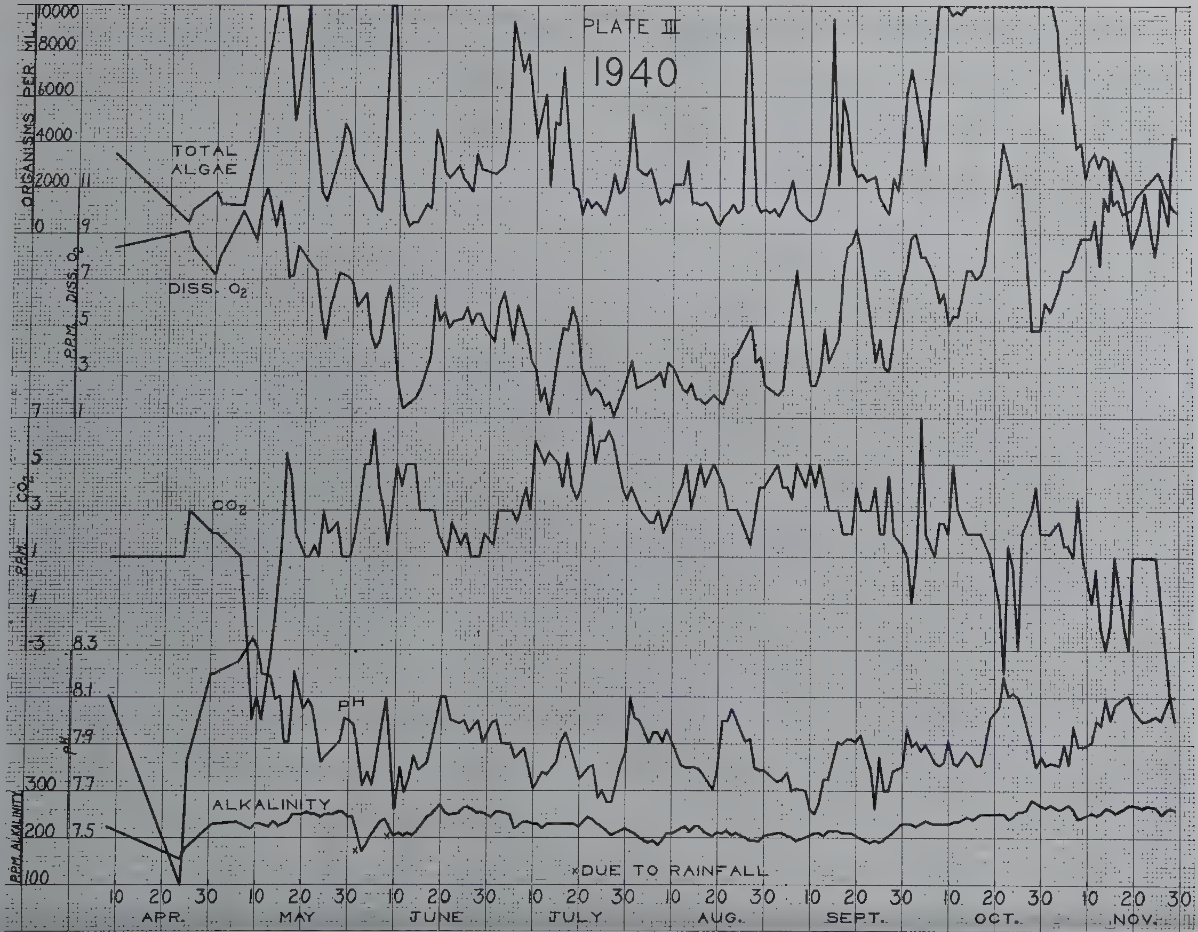


PLATE III

1940

By plotting the daily results (plate III) there is a very close correlation between total algae, dissolved oxygen, carbon dioxide and pH. As previously shown each plankton rise was accompanied with a rise in dissolved oxygen and pH while the carbon dioxide decreased.

The silicate and phosphate determinations were limited in number and were made only in the latter part of the season. During this time there were two diatom peaks and each seemed to correlate with the soluble silicates in that there was a very rapid decrease in silicates as the diatom population increased. There was no correlation between phosphates and plankton, but this may have been due to technical difficulties experienced in the determination of phosphates.

The ammonia and nitrite nitrogen did not correlate with plankton changes although the semi-monthly averages of nitrate nitrogen rose to 4.3 ppm and immediately began to fall as the plankton approached its spring peak. As the plankton declined, the nitrate nitrogen again increased to 3.08 ppm on June 15, and immediately decreased until July 15, at which time the plankton had reached another peak. This seems to indicate that nitrates were utilized by the increasing plankton and may have been essential in its multiplication. If the source of nitrates remains constant and their concentration is not lowered by dilution, then possibly a sharp reduction of them might be used as an indication of a subsequent plankton pulse.

The alkalinity was affected on three different occasions during the spring rainfall, but during the remainder of the year when rainfall was negligible, there was no indication that it or bacterial counts were functions of plankton pulsations.

During early spring the temperature of the water increased quite rapidly from 11° C. to 18° C., accompanied by a high plankton peak, 50% of which were diatoms. There was no definite relationship of temperature to plankton during the warm summer weather and the water temperature had fallen to approximately 16° C. before the autumn pulse began. This pulse, which consisted almost entirely of diatoms, remained high for about one month, the end of which occurred as the water temperature fell rapidly from 12° C. to 1° C.

The semi-monthly averages were tabulated (table I) and those factors which correlated with total algae were graphed (plate VI). The total algae did not correlate with dissolved oxygen, carbon dioxide and pH during the last of June, but by using the graphs representing daily results these factors correlated very well during this time.

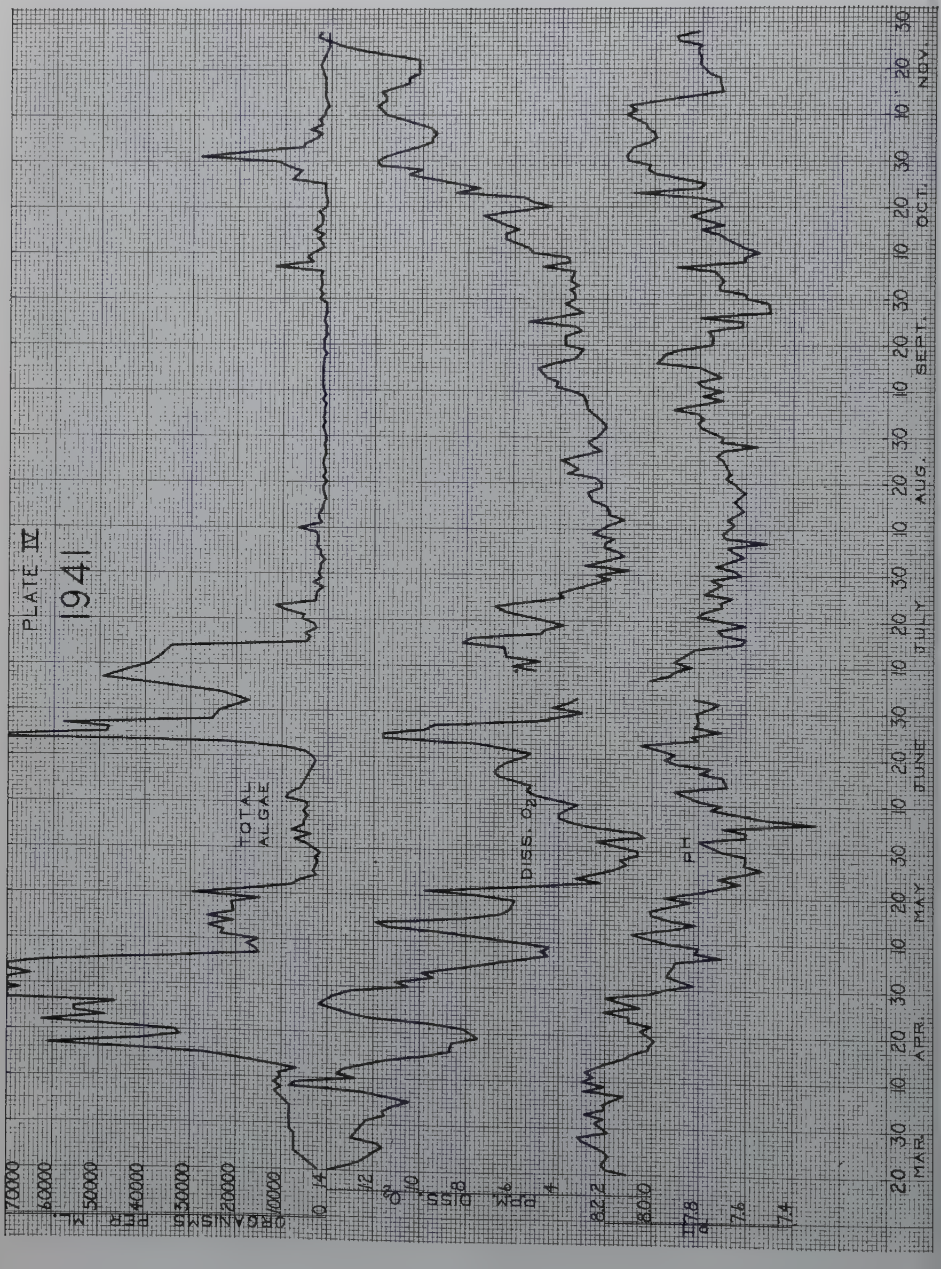


PLATE IV
1941
TOTAL ALGAE
DISS. O2
PH
ORGANISMS PER ML.
70000
60000
50000
40000
30000
20000
10000
0
14
12
10
8
6
4
DISS. O2 PPM
8.2.2
8.0.0
7.8
7.6
7.4
PH
20
30
MAR.
10
20
30
APR.
10
20
30
MAY
10
20
30
JUNE
10
20
30
JULY
10
20
30
AUG.
10
20
30
SEPT.
10
20
30
OCT.
10
20
30
NOV.

1941

This season's work included total algae, Chlorophyceae, diatoms and the same physical and chemical data as in 1940 with the exception of phosphates and 37° bacteria.

The total algae (plate IV) reached its vernal peak during the last of April and the first of May. The flora of this pulse consisted of about equal proportions of diatoms and Chlorophyceae, although the diatoms preceded the Chlorophyceae both in initial preponderance and in reduction by 3 to 4 days. The second pulse consisted of a split peak, the first section occurring in the last of June and the second during the first part of July. The first section of this pulse contained twice the number of diatoms as Chlorophyceae while the second section contained a few more Chlorophyceae than diatoms. The third and last pulse of the season occurred on the first of November and consisted almost entirely of diatoms, tentatively identified as Cyclotella and Synedra. The autumn peak of this season occurred later than in any of the three previous years probably due to the low rate of flow through the canal which is explained later.

Graphs representing daily results show that total algae, dissolved oxygen and pH curves (plate IV) parallel each other during their fluctuations while the carbon dioxide curve (plate V) is inversely related. These three chemical curves are more closely related to the diatom curve (plate V) than to either the Chlorophyceae or total algae. The alkalinity and ammonia curves had no correlation with algae, but nitrites, nitrates, and silicates were usually high preceding a plankton pulse and decreased rapidly just before the peak was reached. The nitrites and nitrates correlated fairly well with total plankton while silicates correlated with diatom pulses (plate V).

Water temperature increased rapidly during early spring. It rose 18° C. from March 20, to April 19. On April 9, there was an Euglena bloom as the water temperature reached 12° C. Immediately following the Euglena bloom was the vernal plankton pulse at which time the water temperature was 16° C. During the warm season there was no relationship of temperature with plankton. The autumn peak of diatoms occurred in a cooling water that had fallen to 12° C.

There was very little rainfall during the year, and most of that occurred in the first half of June. The rainfall of this time apparently had little or no effect on plankton; although, there was a mid-summer peak as the river declined to normal summer flow.

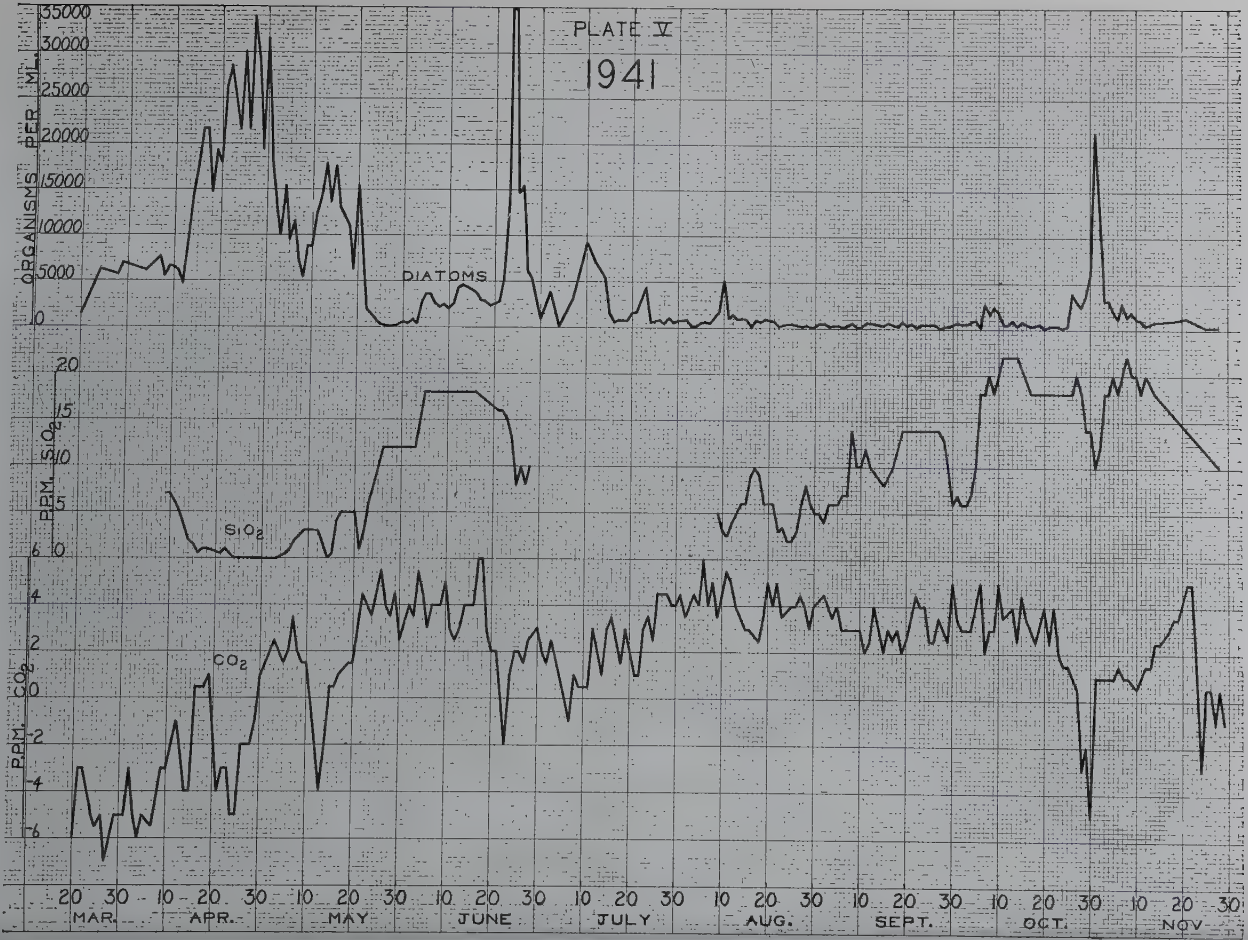


PLATE V

1941

ORGANISMS PER ML.
35000
30000
25000
20000
15000
10000
5000
0
DIATOMS
P.P.M. SiO$_2$
20
15
10
5
0
SiO$_2$
P.P.M. CO$_2$
6
4
2
0
-2
-4
-6
CO$_2$
20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30
MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV.

DISCUSSION

During the four years of study the rhythm of plankton pulsations seemed to be fairly constant, but the magnitude was different from year to year (plate VI). The vernal pulses occurred in April or May, followed by summer pulses occurring in June or July, and in August during 1938 and 1939, and the autumnal pulses occurred in October during 1938, 1939 and 1940 and in November during 1941. Previous work by Calvert (2) in 1920 on water in the White River canal showed a peak occurring in September. In 1934, a similar study by Coffing (3) on water in the White River canal showed two peaks, one during June and the other during October.

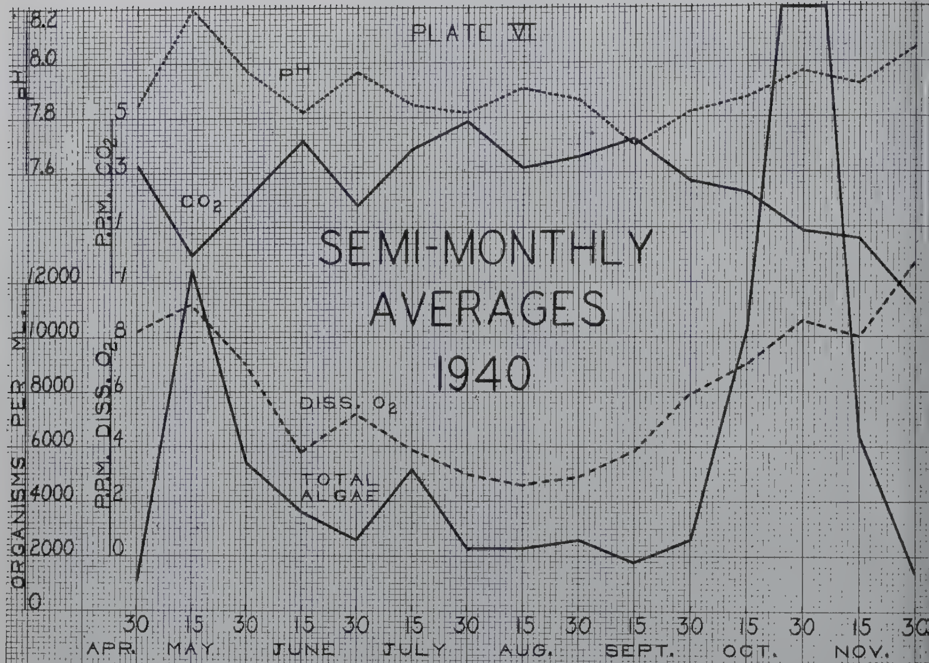
Fluctuations of total algae were closely correlated with dissolved oxygen, pH and carbon dioxide, i. e. with plankton rises there was an increase in dissolved oxygen, a higher pH and a decrease in carbon dioxide. These conditions do not exist during the winter months because of the low water temperature, thus permitting greater solubility of gases. There seemed to be a general tendency for the nitrites, nitrates and silicates to diminish preceding a plankton rise which was especially true of the latter when compared with diatom pulses.

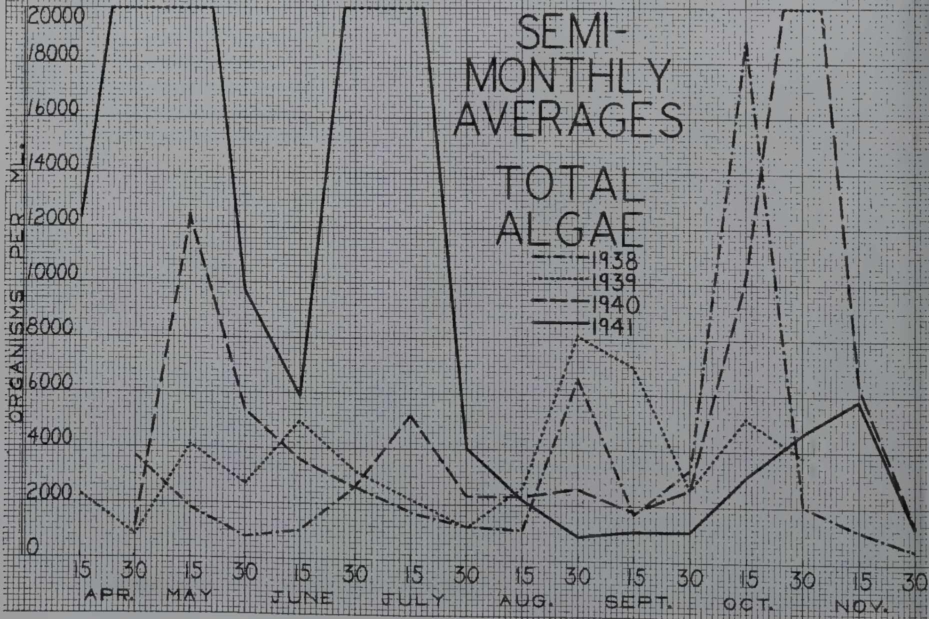
The diatom pulses were usually limited to spring and fall while Chlorophyceae were more abundant after the spring diatom peak and during the warmer months. The vernal peak never occurred in a water having a temperature of less than 10° C., while the autumn peak always occurred before the water had cooled to 10° C. These two extremes usually supported diatom pulses. As the water temperature increased during late spring and summer, there was apparently no correlation with plankton. During the early spring previous to any plankton pulse, there were quite often minor plankton fluctuations which ran parallel with changes in water temperature.

The plankton population of many streams is affected by factors usually not found in lake waters isolated from metropolitan areas. Sewage and industrial wastes affect plankton both quantitatively and qualitatively. Since the year 1940, sewage has been effectively treated by disposal plants of two cities upstream from Indianapolis, but previous to that time, White River received the bulk of these discharges as raw untreated sewage. The stream was always rich in nutrient material thus establishing optimum conditions for plankton multiplication.

The quality of the plankton is affected by sewage in that the type

PLATE VI


SEMI-MONTHLY AVERAGES 1940


SEMI-MONTHLY AVERAGES TOTAL ALGAE

of flora changes from an area of pollution to one of relatively clean water. These pollutional and clean water types were demonstrated by Lackey (8) in his work on the Scioto River and by Palmer (11) in his work on White River below Indianapolis. Industrial wastes are also a major factor in determining the type of organisms found in streams receiving such discharges. Some organisms are especially tolerant to extreme conditions while many others are completely inhibited as is shown by Lackey in his work on streams receiving acid mine waste (9) and distillery wastes (10).

Rate of stream flow is also a factor in determining the number and kind of organisms found at any sampling station on the stream. Plankton numbers usually decrease immediately below a point of heavy sewage pollution and then gradually increase downstream as bacterial action on organic material proceeds and finally begin to decrease again as the nutrient material is utilized and the cycle is completed. The location of highest plankton population may be constant or it may move either upstream or downstream. A low sluggish stream will keep the heavy plankton relatively close to the point of sewage pollution while a swift stream will move the plankton peak farther downstream.

During the summer months of 1940 and '41, several river surveys were made upstream from Indianapolis. On September 30, 1940, a survey of this sort was made, which included sixteen sampling points. The farthest upstream sampling point included Chesterfield, Indiana, which is approximately seven miles above Anderson and 57.5 miles from Indianapolis. The remaining stations were consecutively located downstream, the last two being canal stations at Indianapolis. The sampling of these stations was done by working downstream from Chesterfield, taking the first sample at 10:45 A. M. and the last (Indianapolis Water Company intake) at 2:50 P. M. The samples were immediately taken to the laboratory and worked as soon as possible. Plankton samples were usually stored in the refrigerator until the next day.

The results (table II) showed that the plankton was relatively low above Anderson with a gradual increase until the stream received the Anderson sewage and then remained fairly constant until the stream began its natural purification at which time the plankton rapidly increased to large numbers. The plankton peak was reached at Northern Beach, 16 miles from Indianapolis, and then began its sharp decline as the water progressed downstream.

The dissolved oxygen parallels the plankton except just below Anderson which is due to the oxygen demand of sewage contributed by Anderson at a point just above Moss Island. The carbon dioxide is inversely related to plankton except when affected by the Anderson sewage.

The ammonia, nitrites and chlorides were good indicators of sewage pollution while the silicates and phosphates were as high above the Anderson sewage outfall as they were below and continued to decrease as the water continued downstream. The water entered the White River canal containing only a trace of ammonia and increased as the water traveled through the canal, which received no outside pollution. This increase in ammonia is thought to be due to the decaying algal cells of a diminishing plankton.

The decreasing amounts of phosphates and corresponding increase in plankton as the water progressed downstream, indicated that the plankton may have utilized the soluble phosphates in their metabolism. There was also a decrease in silicates downstream from Northern Beach as the diatoms increased, reaching their peak at the canal head gates, thus indicating that soluble silicates may have been utilized by the diatoms. The results of other river surveys by previous workers reveal that the same conditions as outlined above were true during the time they were studied.

If the plankton peak can be held upstream by decreasing the rate of water flow a low plankton can then be expected at the intake of the Indianapolis Water Company, where its presence is certainly not desirable. Establishment of these conditions was realized during the summer of 1941 when the river level was low, and the lower canal gates were closed, permitting only the amount of water being actually used by the water company to flow through the canal. During this time the plankton was excessively heavy upstream but had greatly reduced by the time the water reached the intake. The high plankton peak during November at the intake occurred after the canal gates had been opened and the rate of flow greatly increased. The autumnal peaks during the three previous years occurred periodically within two weeks of each other during October. The reduction in rate of flow during that period of 1941 is considered as responsible for the delayed peak.

CONCLUSION

1. The vernal and autumnal plankton peaks were fairly constant from year to year in their periodicity and were usually the major

peaks of the season. The diatoms reached their maxima during these two peaks. Those peaks which occurred during the summer were quite often represented by excessive numbers of organisms but were of short duration; therefore, they were considered as minor peaks.

2. The high plankton peaks were accompanied by an increase in dissolved oxygen and pH and by a decrease in carbon dioxide, nitrites, nitrates and silicates. Obviously, the fluctuations of dissolved oxygen and carbon dioxide were merely the results of photosynthesis, while pH seemed to be governed by the amount of free carbon dioxide, i. e., the greater the carbon dioxide content of the water the lower the pH.

3. The nitrite and nitrate content of the water decreased previous to plankton pulses represented by a mixed flora, thus indicating that these compounds were essential for multiplication of most planktonic organisms.

4. The soluble silicates decreased prior to increases in diatom populations but did not correlate very well with other types of organisms.

5. A decrease in nitrites, nitrates and silicates might be used as an indication of an impending plankton pulse represented by diatoms or a mixed flora and a decrease in only nitrites and nitrates with silicates remaining fairly constant would indicate that the flora would be deficient in diatoms.

6. River surveys above the sampling point showed that the heaviest plankton population was always downstream from the point of sewage pollution, and the location of the plankton peak seemed to be governed by the rate of river flow. This is due, probably to the fact that bacteria must change the character of the organic matter of the sewage before it can be utilized by most algae. With water temperature remaining constant, bacterial decomposition of the organic matter takes place at a given rate; therefore, an increase in rate of flow extends the decomposition process and the plankton peak farther downstream.

ACKNOWLEDGMENT

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TABLE I

Showing semi-monthly averages, 1938-1941

	Total Algae per ml	Diatoms per ml	Dissolved O_2 ppm	CO_2 ppm	pH	Alkalinity ppm	NO_2 ppm	NO_3 ppm	SiO_2 ppm	Rate of River Flow cu. ft. per. sec.
1938										
Apr.			9.4	3.5	7.60	137				9,300
	3,700		9.2	.04	8.07	237				1,165
May	1,820		8.9	.8	8.05	247				568
	780		7.5	1.7	7.91	225				1,382
June	1,030		6.8	2.2	7.98	221				1,510
	2,560		6.5	3.4	7.90	203				2,761
July	1,660		6.1	2.8	7.98	232				1,703
	1,204		5.7	1.2	8.00	240				530
Aug	1,070		4.6	1.4	7.90	222				663
	6,600		6.4	2.4	7.90	232				261
Sept.	1,685		5.4	5.3	7.74	214				248
	3,270		6.1	3.1	7.80	226				311
Oct.	18,830		8.9	3.5	7.92	238				159
	2,090		7.3	3.7	8.00	269				175
Nov.	1,180		8.7	1.0	7.96	278				189
	535		10.6	.8	8.00	242				392
1939										
Apr.	2,252		11.8	—2.1	8.26	232				875
	763		8.7	3.7	7.75	139				6,110
May	4,103		9.3	.1	8.15	228				810
	2,690		6.6	.4	8.05	244				461
June	4,990		5.0	1.9	7.85	233				374
	3,160		4.4	1.9	7.85	219				651
July	2,325		6.2	.6	7.97	217				357
	1,235		4.6	.6	7.73	182				794
Aug.	2,555		4.8	1.2	7.89	214				332
	8,100		6.2	.9	7.83	204				329
Sept.	6,975		4.7	2.6	7.73	216				128
	2,590		5.3	1.9	7.93	244				100
Oct.	5,200		5.4	1.3	7.90	266				122
	3,770		6.8	1.5	8.00	263				185
Nov.			8.4	2.4	7.85	250				173
			9.8	1.2	7.97	276				178

TABLE I—(Continued)

Showing semi-monthly averages, 1938-1941

	Total Algae per ml	Diatoms per ml	Dissolved O_2 ppm	CO_2 ppm	pH	Alkalinity ppm	NO_2 ppm	NO_3 ppm	SiO_2 ppm	Rate of River Flow cu. ft. per. sec.
1940										
Apr.	1,137		8.2	3.3	7.85	169	.086	4.30		3,456
May	12,473		9.2	—.04	8.20	226	.119	2.59		729
	5,380		7.0	2.1	7.97	249	.082	1.09		449
June	3,580		3.8	4.2	7.82	211	.192	3.08		720
	2,635		5.2	1.8	7.97	257	.110	1.72		287
July	5,150		3.9	3.9	7.85	236	.035	.33		181
	2,270		3.0	4.9	7.82	225	.041	.29		134
Aug.	2,310		2.6	3.2	7.91	207	.010	.16		104
	2,620		2.9	3.6	7.87	207	.028	.58		89
Sept.	1,840		3.8	4.2	7.70	205	.024	.40		75
	2,560		5.9	2.7	7.82	205	.016	.30		72
Oct.	10,160		7.0	2.3	7.87	233	.018	.42		88
	45,600		8.6	.9	7.97	275	.046	.50		128
Nov.	6,430		8.0	.6	7.92	259	.117	1.80		132
	1,440		10.7	—1.7	8.05	263	.203	2.24		126
Dec.	742		12.3	—1.7	7.99	267	.250	1.67		141
	2,330		10.6	—3.3	8.09	234	.210	2.78		267
1941										
Apr.	12,329	8,287	12.4	—3.9	8.22	207	.145	1.19	4.6	319
	55,348	24,125	10.9	—1.8	8.06	209	.109	.70	.4	241
May	37,949	12,338	8.0	.8	7.88	222	.078	.30	1.3	158
	9,660	4,322	4.0	3.0	7.75	224	.079	.45	6.6	125
June	5,872	2,470	3.3	3.8	7.68	168	.135	5.24	15.0	1,278
	25,182	9,086	7.1	2.6	7.83	198	.075	4.73	12.7	612
July	29,141	4,323	5.3	1.3	7.83	196	.034	.62		248
	3,951	1,192	4.4	3.1	7.70	186	.038	.70		151
Aug.	2,234	1,153	1.8	4.3	7.65	184	.027	.25	4.1	85
	905	405	2.8	3.8	7.67	194	.020	.27	5.6	80
Sept.	1,147	416	3.3	3.2	7.82	204	.028	.40	8.1	91
	1,081	458	3.7	3.2	7.75	196	.019	.24	12.4	55
Oct.	3,064	1,060	4.5	3.5	7.69	175	.131	1.14	15.5	
	4,656	2,250	8.5	1.1	7.90	200	.090	2.27	18.0	
Nov.	5,939	4,093	10.8	1.3	8.01	219	.153	2.27	18.0	
	1,254	830	12.3	1.5	7.82	226	.197	2.60	12.0	

TABLE II

Showing the White river survey, September 30, 1940.

Sampling Point	Approx. Dist. in Miles	Time	Temp. °C.	Diss. O_2	Alk.	Chlorides	Parts per Million CO_2	NO_2	NH_3	SiO_2	PO_4	Total Algae per ml.
Chesterfield	0	10:45a	16.	5.0	289	37	0	.16	2.64	16.	.36	1,952
4 mi. above Anderson	3	11:00	16.5	5.4	280	32	—0.5	.20	2.28	16.	.40	2,523
Anderson (bridge)	7	11:10	21.5	8.6	294	34	—7.0	.20	2.32	17.	.35	3,442
Moss Island	10	11:40	19.	5.0	313	34	—3.0	.08	4.20	18.	.25	6,014
Hamilton Bridge	14.3	11:55	18.	5.0	305	32	—2.0	.40	2.00	16.	.10	5,757
Perkinsville	18.8	12:10p	17.25	9.8	280	32	—8.0	.18	.34	14.	.06	6,786
Strawtown	23.5	12:25	18.5	11.4	269	28	--9.0	.06	.21	8.	.01	10,280
Riverwood	28.0	12:35	17.75	12.8	261	29	--11.0	.05	.16	8.	.01	44,760
Potters Bridge	30.4	12:45	17.75	15.4	247	27	—13.0	.02	.06	9.	.01	46,940
Noblesville (Iron bridge)	32.7	1:00	16.75	14.6	238	26	—14.0	.02	.02	8.	0	49,543
State Road No. 234	36.7	1:35	17.75	12.4	255	27	—12.0	.03	.06	10.	0	101,893
Northern Beach	41.7	1:50	17.5	14.2	248	24	—13.0	.015	.04	11.	0	107,493
86th St. Bridge	46.9	2:10	17.5	10.0	258	22	—10.0	.04	tr.	7.	0	28,087
Above Canal Head Gates	51.5	2:25	17.	15.0	236	21	—12.0	.01	tr.	2.	0	40,151
Northwestern Ave.	54.5	2:40	16.75	6.4	231	20	—1.0	.015	.17	1.5	0	9,565
Indianapolis Water Co. Intake	57.5	2:50	17.	8.8	228	20	—2.0	.01	.22	1.6	tr.	4,863

POLLEN STUDY OF FIVE BOGS IN PRICE AND SAWYER COUNTIES, WISCONSIN*

By J. E. Potzger

The bogs included here constitute the second unit of a transect westward of Vilas county. The first unit of 4 bogs was discussed by Potzger and Keller (8) in a previous study. The problem was to trace vegetational succession in Wisconsin along a given latitude, and specifically to discover whether Quercus became more important in the forest associations towards the western part of Wisconsin than it was in Vilas county and in adjacent Gogebic county, Michigan. The bogs selected are all close to highway 70 as the most suitable westward line from the Trout lake area. Four are located in Price and one in Sawyer county, Wisconsin.

LOCATION AND DESCRIPTION OF THE BOGS

Figures 1 and 2 present the bogs in successional order, beginning with the easternmost, Sheep Ranch Road bog.

Sheep Ranch Road Bog

This is a valley type bog, located three miles south of highway 70, on the western side of road 390, or Sheep Ranch Road. At this point it widens into a rather large oval basin but as a whole occupies a rather narrow valley set in between steep uplands. It was with some difficulty that the deepest part of the original basin could be determined. Poorly preserved remnants of the former forest gave the impression that northern hardwoods (*Acer saccharum,* Tsuga and *Betula lutea*) constituted the forest cover when civilized man first appeared. A luxuriant growth of Sphagnum crowned the surface layer. Westward of the wide basin, in the narrow valley part of the bog, dense stands of Picea and Abies constituted the forest cover until in 1938 a severe sleet storm completely destroyed it.

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*This is contribution 144 from the botanical laboratories of Butler University, and notes and reports 118 from the Limnological Laboratory of the Wisconsin Geological and Natural History Survey, University of Wisconsin.

GRAVEL PIT BOG

This bog is also of the valley type. A stand of small *Picea mariana* and *Larix laricina* constituted the forest cover. Its location is 10.8 miles west of the Oneida-Price county line on highway 70. A steep rocky ridge, almost wall-like, separates it from a similar valley bog not more than 50 feet to the west. A gravel pit bordering the highway on the north was, for want of a better designation, selected as the defining name for the bog.

SUNKEN HIGHWAY BOG

Approximately 7.2 miles east of Fifield, Price county, old highway 70 crossed the southern end of an extensive boggy depression, and the soft peat has engulfed the highway, leaving a strip of open water. The surface of the bog is covered by a sedge meadow where *Chamaedaphne calyculata* makes its competition felt. In the center is a 100-foot-wide open pool. The inner portion of the bog is in the quaking mat stage. The boring was made about 35 feet from the southern edge of the pool.

FOUR-MILE LAKE BOG (PLANET LAKE)

A deep-set kettle hole lake is four miles east of Fifield, Price county. A wide mat surrounds the lake which is covered by a dense stand of bog forest in which Picea, Larix and *Betula papyrifera* play a prominent role. The lake has a several-hundred-foot-wide expanse of open water and was reported to have been sounded to a depth of 60 feet. This indicates that the floor has a steep gradient from the shore to the deepest part of the basin.

DRAPER BOG

This extensive bog area, too, has a shallow central open pond. Its location is 5 miles northwest of Draper, Sawyer county, Wisconsin. The vegetation on the mat is primarily sedge-meadow with scattered clumps of *Chamaedaphne calyculata.* A dense bog forest covers the periphery of the wide mat which, near the pond where the boring was made, is evidently still in the floating stage, because the borer did not receive the necessary resistance to take samples at the topmost 8 foot-levels.

METHODS

Borings were made with the open cylinder and movable-sleeve type borer. In every case several soundings were made to determine the deepest part of the basin. The samples for analysis were taken from the center of each core. The peat was placed into bottles which were properly labeled with location and foot-level. No preservative was added. At the laboratory the stoppers were sealed with paraffin to keep the soil moist. Preparation of slides followed closely the Geisler method (2). Two hundred pollen grains of tree genera constituted the count for any given foot-level. Exceptions to this rule were at: Sheep Ranch bog, 22-foot level (50 grains), Draper bog, 28.25-foot level (150 grains), Draper bog, surface level (100 grains).

Pollen of grasses, Compositae, Alnus, Corylus and Chenopodiaceae were tabulated but not included in the count of 200 grains of tree genera.

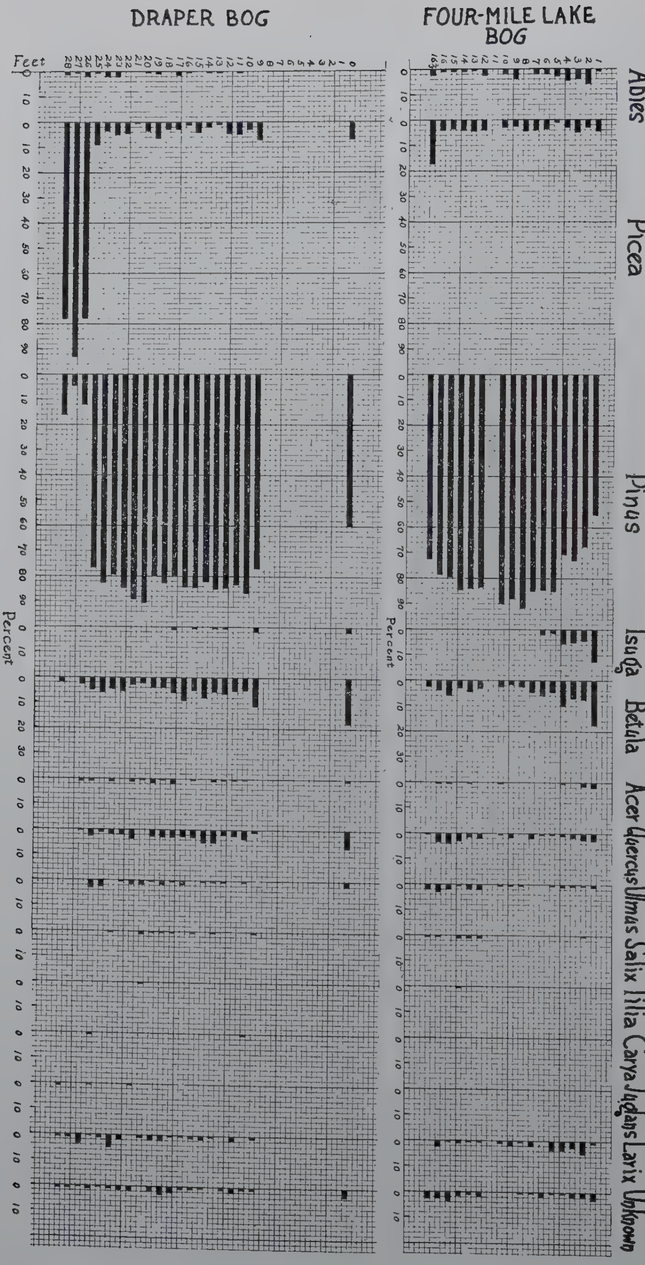
RESULTS

All bogs except the one at Four-mile lake record an initial Picea period of pronounced prominence. The reason for absence of this period in the bog just named is, no doubt, to be sought in the location of the sampling station on a floor with a steep slant toward the deepest portion of the basin, now occupied by the lake. Such "off-center" borings generally result in a truncated lower portion of the pollen profile, usually eliminating the entire or major portion of the Picea period.

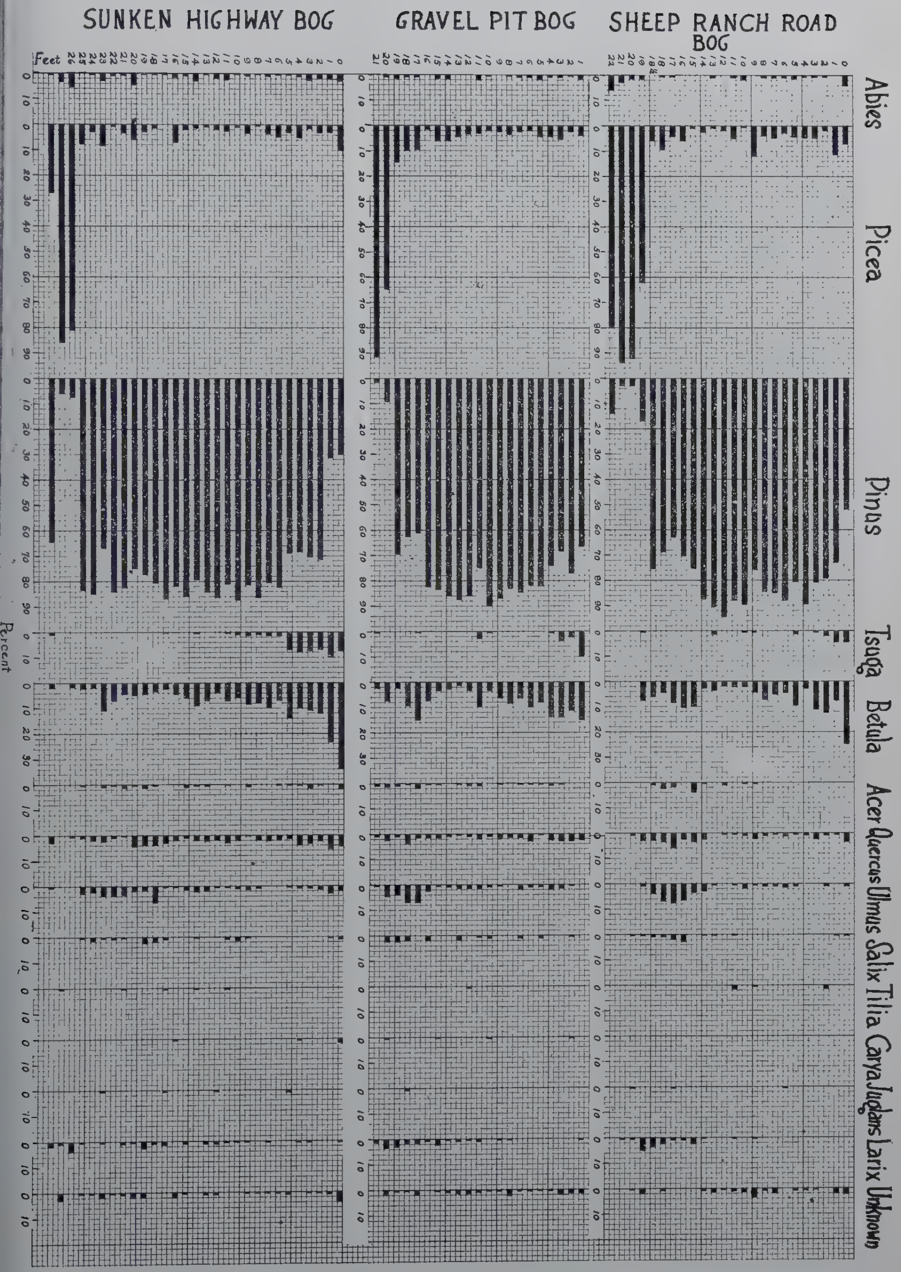
A second non-conformity is found in Sunken Highway bog where Pinus shows greater abundance than Picea in the lowest level, and is replaced in this respect by Picea in the succeeding two foot-levels. Decline of Picea is, as in all previously studied bogs in Wisconsin, very sudden. In the Sheep Ranch Road bog, between the 19- and 18.5-foot levels Picea declined from 62 to 6% (fig. 1). Pinus controlled the forest cover during a period of time represented by 75 to 90% of the foot-levels. Only in the Sheep Ranch Road and Sunken Highway bogs is a very decided decline in percentage of Pinus pollen recorded. Increases in Betula and Tsuga account for most of the decline in the prominence of Pinus while the topmost levels were accumulating. Tsuga is comparatively a very late entrant into the forest complex in Price and Sawyer counties. Ulmus shows the greatest representation at the time the broadleaved genera invaded the region, and declined towards the closing foot-levels of the various bogs. Carya and Juglans appear in a number of levels in all but the Four-mile Lake bog. (Carya is also absent in the Sheep Ranch Road bog.) The comparatively small number of foot-levels recording a decided Picea period hints at the probability that pollen-bearing sandy layers were of necessity omitted by limitations of action of the sleeve-type borer in sandy deposits. Climatic climax for this part of Wisconsin is evidently also the broadleaved forest and Pinus maintains an undisputed dominance only in the poorer sandy soils, reflecting thus, the same status as in the Vilas county neighborhood.

DISCUSSION

Succession of forests since late Wisconsin glaciation was approximately the same in Price and Sawyer counties as in the Vilas county neighborhood. Except for Sunken Highway bog and Four-mile Lake bog, northern hardwoods (Betula-Tsuga) invasion is not very well accentuated. Apparently the locations represented are more of the sandy habitat types which, as Potzger and Richards (10) and Potzger (6) pointed out, are a microclimatic factor which maintains forest cover dominated by Pinus. The pollen spectra (figs. 1 and 2) suggest strongly that northern hardwoods invaded later in the locations represented by the five bogs than in the Gillen Nature Reserve (Potzger, 6). Quercus indicates no climatic difference in these more westward extending counties than in Vilas county, never exceeding 6% and suggesting no marked warm-dry climatic period. Representation of grass pollen indicates no special climatically favored period for prairie invasion. Its representation increased somewhat in the topmost levels but never exceeded 5% of the total tree pollen. The fact that pollen of Compositae rises suddenly in the surface levels, especially in the Sheep Ranch Road bog points to a solidifying mat on which moisture-demanding grasses and composits could invade. Location of boring in the bog and possible omission of several feet of sand are suggested by absence of or limited foot-levels showing Picea dominance. The boring in the Four-mile Lake bog had to be made too far from the deepest portion of the basin to include sediments laid down during the Picea period. All bogs had sandy bottom layers of which only one foot-level could be obtained with the movable-sleeve type borer, and this very likely resulted in a truncated lower portion of the cores. Such omissions have been shown by Wilson and Potzger (12) in their study of Minnesota lakes, where up to



DRAPER BOG
FOUR-MILE LAKE BOG
Feet
Percent
Abies
Picea
Pinus
Tsuga
Betula
Acer
Quercus
Ulmus
Salix
Tilia
Carya
Juglans
Larix
Unknown


SUNKEN HIGHWAY BOG
GRAVEL PIT BOG
SHEEP RANCH ROAD BOG
Feet
Percent
Abies
Picea
Pinus
Tsuga
Betula
Acer
Quercus
Ulmus
Salix
Tilia
Carya
Juglans
Larix
Unknown

nine feet of sandy deposits were pollen-bearing. This same feature was discovered by Potzger and Richards (10) in Forestry Bog Lake in Vilas county, Wisconsin, where special effort was made to secure samples from sandy sediments. Pollen of the Picea period was embedded in 8 foot-levels of fine sand, which more than doubled the number of foot-levels in other bogs of the area showing Picea dominance. If these sandy layers had been omitted, the Picea period would have been recorded in only one foot-level. Wilson and Potzger (12) experimented with a new method to secure samples from sandy sediments which worked effectively in Anoka county, Minnesota, and is described in detail in the paper discussing the results of the study.

The "non-conforming" high representation of Pinus in the 28-foot level of Sunken Highway bog which yielded to an almost absolute control by Picea while the 27- and 26-foot levels were laid down, presents a puzzling problem, which is made more complex by the fact that the 28-foot level was located in sand. Since three of the 5 bogs show a decline of Pinus in the second and third lowermost levels (figs. 1 and 2), it may possibly be a microclimatic feature of the region. Potzger and Richards (10) show the same behavior of Pinus in the profile from Forestry Bog lake and Cardinal bog. Potzger and Keller (8) found a similar condition in the Mud Creek bog and Bog "E"; Wilson and Webster (14) found a similar condition in the Winchester bog but the initial peaks in Pinus representation were not so high as in the Sunken Highway bog.

Tsuga, again, very definitely, shows alliance with the broadleaved element. As pointed out by Potzger (6) for Wisconsin, by Wilson and Potzger (13) for northern Michigan and by Potzger and Otto (9) for New Jersey, Tsuga apparently always invades with broadleaved genera long after the Pinus period had control. The pollen records support the conclusions by Whitford (11) that the hemlock-deciduous species association is the climatic climax for the lake forest.

Wilson and Webster (14) discussed in considerable detail representation of Carya and Juglans recorded in a pollen profile from a bog near Winchester, Vilas county, Wisconsin. Their arguments very correctly claim that presence of certain genera, even though their pollen frequency is low, may be of important significance in the interpretation of former distribution of such genera as well as in reconstruction of climatic features which made such distribution possible. The author's recent pollen investigations bring considerable additional information on the former distribution of the 2 genera named above, and for that reason will be discussed in detail here. Potzger (6) reported Juglans from 2 of 4 bogs in the Gillen Nature Reserve (involving northern Vilas county, Wisconsin, and southern Gogebic county, Michigan). Potzger and Richards (10) list Carya and Juglans for 4 of 5 bogs located in the environs of Trout Lake, Vilas county. Potzger and Keller (8) recorded Carya in 5 foot-levels of Bog "E" and Mud Creek bog and 2 foot-levels in Mid Lake bog in Oneida county. Juglans was recorded in 5 levels in Mud Creek bog and in 2 levels in the Mid Lake bog. Juglans also appeared in the topmost 3 foot-levels of Forest Lake bog in Vilas county, approximately 24 miles east of the Winchester bog. Potzger (ms.) found pollen of Carya and Juglans in profiles from 2 bogs in Hubbard county in west-central Minnesota. The range is extended eastward to the lower peninsula in Michigan when Wilson and Potzger (13) reported pollen of Juglans in 4 foot-levels from Middle Fish lake in Montmorency county and at the 85-foot level (total depth 102 feet) of Douglas Lake, Cheboygan county. Carya likewise was recorded in 4 foot-levels in each of the 2 lakes named above. These pollen records extend the former reported range of Carya and Juglans during early post-Pleistocene times westward to western Minnesota, northward to Gogebic county, Michigan and eastward to the upper part of the lower peninsula of Michigan. The recorded distribution in Wisconsin is from the westernmost station in Sawyer county (present study) in an almost unbroken series of locations along highway 70 across Sawyer, Price, Oneida and Vilas counties to the easternmost Forest Lake bog (Vilas county).

We draw attention to the reported presence of *Juglans cinerea* by Potzger (5) in the northern hardwoods near Skull Cave, Mackinac Island, Michigan. This last-named report places *Juglans cinerea* in its present range comparable to the reported post-Pleistocene northward and eastward distribution. It is of course impossible to place the migration of these genera into late postglacial times as Wilson and Webster favor. In Douglas lake these genera appeared already in the 97-foot level (total depth 102 feet). In Gogebic county, Michigan, in the 20-foot level (total depth 22 feet) and in the Cardinal bog at Trout lake, Vilas county, Juglans appeared in the 22-foot level and Carya in the 20-foot level (total depth 22 feet). All these records point to an early invasion, coming at or soon after decline of the Picea period.

This writer also cannot share the opinion of Wilson and Webster

(14) that we are "at present experiencing a period of decreasing climatic warmth." So many concrete evidences have been published in recent years which show definitely exactly the opposite of such a conception that one reads such postulations with surprise. Cooper (1) and Griggs (3) have shown that vegetation in Alaska is advancing northward, and glaciers are retreating. Potzger and Friesner (7) pointed out that in all profiles from Indiana bogs, pollen of Pinus is present to the topmost levels but aged pioneers of such locations usually assure us that no Pinus was present when the country was first being settled. These same authors point out that in Indiana, which is the southernmost rim of that great migration route of boreal and southern species on their northward march, relic boreal species occupy a very precarious position and disappear when their habitat is at all disturbed. Above all, attention should be drawn to the striking reports of the American Geophysical Union which for years have expressed alarm at the rapid retreat of our western mountain glaciers as well as of those in Alaska. Matthes (4) says in his 1942 report, "William O. Field, Jr.'s revisit to Glacier Bay during the summer of 1941 revealed in general widespread diminution of glacier ice since his last visit in 1935. Nearly all the glaciers had receded considerably." For Glacier National Park the report is, "unabated continuance of the rapid wasting of the glaciers in the park." Kincer (15) brings evidence that this moderating climate also involves the central and eastern sections of our country. He says, "There has been a marked tendency to relatively high temperatures since the turn of the century. . . . Southeastern Iowa has twenty days longer frost-free growing season than forty years ago, and the Washington, D. C., winter climate is comparable to that of south-central Virginia of forty years ago." G. S. Callendar (quoted by Kincer) reports the same trend to higher temperatures for Europe.

Considering gross features of the forest succession in the Price-Sawyer county study we must say it was from Picea (Picea-Pinus) to Pinus to northern hardwoods type. During this last period edaphic factors influenced the degree of expression or prevented entirely the establishment of the climatically favored hardwoods. Climate favorable to Pinus has persisted longer in these two counties than the other climatic periods combined, being identical in this respect, as well as in the progress of succession, to the Vilas county section.

SUMMARY

1. Pollen profiles from 5 bogs in Price and Sawyer counties, Wisconsin, are presented. They constitute a section of a line transect along highway 70 westward from the lakes area in Vilas county.
2. The specific aim was to ascertain whether the Quercus extension into the southwestern part of Minnesota has, in early post-Pleistocene times, affected a wider area in northern Wisconsin.
3. Succession in forests is essentially the same in Price and Sawyer counties as in Vilas county, which in its gross features was Picea (Picea-Pinus) to Pinus to Pinus-northern hardwoods.
4. Apparently the hemlock-northern hardwoods forest is climatic climax in which Pinus occupies a post climax position favored by edaphic factors in sandy habitats.
5. Ulmus had its highest peak of representation at the time when broadleaved genera invaded the region, and declined towards the closing levels in the bogs.
6. Quercus at no time suggests a climate favorable to its expanding development as a vital component in the crown cover of the forests.
7. Grasses give no evidence of a xerothermic climate with extension to prairie into this part of Wisconsin.
8. Carya and Juglans show a persistent non-aggressive presence in the forest since the close of the Picea period. Their distribution is discussed in detail and pollen studies are quoted which show their former range as from west-central Minnesota to Gogebic county, Michigan, eastward to the northern point of the lower peninsula of Michigan; and in Wisconsin from the westernmost Sawyer county in an almost uninterrupted series of bogs to Oneida county and the most eastern location in Forest Lake bog.

ACKNOWLEDGMENTS

Appreciation is expressed to the Wisconsin Geological and Natural History Survey for the opportunity to serve on their staff during the summer of 1940; to the Wisconsin Alumni Research Foundation for financial aid to carry on the field work. Thankful recognition is also given Messrs. Thomas H. Flanigon, Sidney Gottlieb and the late Charles Lines, members of the staff at the Limnological Station in 1940, for assistance in the boring work. It is also gratefully acknowledged that Miss June Davis and Matthew Harmon, major students in botany at Butler University prepared the slides for the study of two of the bogs.

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A COMPARATIVE POLLEN STUDY OF THREE INDIANA BOGS[1]

By Carl O. Keller

The topography of the northern half of Indiana is dotted with numerous lakes and bogs. Many of the lakes located north of a line running irregularly southeast from Benton to Randolph counties still have extensive areas of open water, but no natural lakes are found south of this line. There is also a great difference in the stages of maturity of the bogs located in the two areas. Some have small ponds with several feet of water in the central part, some have reached the sedge-meadow stage, and some are completely "verlandet" and are now being utilized for agricultural purposes. These differences are due to three main factors. One is the original depth of the depression to be filled in. Another is the type of vegetation which develops along the shore, since this, as Gates (4) points out, "determines the fate of the area." The primary cause of difference, however, is that of the varying age of bogs. The southern bogs had their beginnings as lakes after the retreat of the Early Wisconsin glaciation. Great blocks of ice were left buried in the glacial drift. These melted, when the climate moderated, leaving "kettle hole" lakes as deep as 50 or 60 feet. The northern bogs are similar as to origin, but younger, since they did not form and begin to fill in until after the retreat of Late Wisconsin glaciation.

A long period of steady, constant change takes place in and about a lake between the time of its origin and its ultimate extinction. Cleland (1) points out that as soon as a lake comes into existence, agencies arise which tend to obliterate it. Sediment begins to accumulate and the outgoing stream commences to deepen its channel, which, in time, may drain the lake. Such drainage, however, does not seem to have been a vital factor in the obliteration of many Indiana lakes. In the numerous bog studies made by faculty members and students in the Botany department of Butler University, only one lake has been reported to have drained out when a little stream cut deep into the retaining embankment. This is a lake which, in ancient times, covered a large part of what is now the Barlow farm in Hendricks county. A study by Potzger (10) of a peat profile from this area shows that the lake must have become drained shortly after the culmination of the spruce-fir period.

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[1] A portion of a thesis submitted to the Faculty of the Division of Graduate Instruction in partial fulfillment of the requirements for the degree Master of Science, in the Department of Botany, Butler University.

The forces most active in obliterating lakes of Indiana have been those of deposition, chiefly in the form of marl and peat. In the Jeff bog, marl had accumulated to a depth of 15 feet before the deposition of peat began. In these marl and peat deposits are found preserved in chronological order, the pollen grains of trees which constituted the forests about the lakes and later bogs from early Post-Pleistocene times to the present. The pollen grains give evidence of succession in vegetation as the lake gradually changed from a body of open water to a wet sedge-meadow, and eventually into a well solidified bog, capable of supporting forest growth. Sediments from lakes show the same story of successional changes (Potzger and Wilson, 14). These lakes even if left undisturbed, would not reach the bog stage for ages to come, although they are slowly filling in year after year. According to Gates (4), a bog mat cannot develop in lakes where wave action is a hindering factor, so we find bogs in depression areas not so large as those of the deeper Indiana lakes, or in protected bays of these lakes. Gates (4) also shows that the initial vegetation developing along the shore of such a depression will be a vital factor in determining whether it will develop into a bog or into a wooded swamp, since the initiation of a bog requires the establishment of a sufficient number of plants of Carex around the edge to form an ecological association.

This study is concerned with the analysis of deposits from three Indiana bogs located within Late Wisconsin territory, but representative of points involving geographical limits almost across the state.

DESCRIPTION OF BOGS

Shipshewana Bog

Shipshewana bog is located at the southeast corner of Shipshewana Lake in La Grange county, Newbury township, Sec. 3, T. 37N., R. 8E. It is near state road 5 and about five miles north of U. S. Highway 20. This bog is one of the deeper multiple basins of a once more extensive body of water. Shipshewana Lake has reached bog stage only in places along the periphery, or in coves which have favored mat formation. No studies have been made of the present vegetation in this area, because the lake has served as a pleasure resort for many years. It is needless to describe the effects of such cultural influences upon the natural plant associations involved. Suffice it to say that most of the typical bog species which should be found have, no doubt, been destroyed by human interference.

Culver Bog

Culver bog is located in Starke county, North Bend township, Sec. 38, T. 32 N., R. 1 W. It is one mile west of the Marshall-Starke county line, and one-half mile south of state road 10. The plant cover at present consists of an extensive Larix-*Rhus vernix* community.

Jeff Bog

Jeff bog is in Wells county, Jackson township, Sec. 14 and 23, T. 25 N., R 10 E. It is 11 miles north of Hartford City, on the east side of state road 3, on the property of Mr. Stockton. The peat samples were taken from an open area about 200 feet east of open water.

METHODS

Sediment samples were taken at one foot intervals with a movable-sleeve-cylinder type of instrument. Two borings were made in each bog, the deeper of them being used in the analysis. The other was retained for comparative purposes. The borer was washed thoroughly between each foot-level boring, and the samples were taken from the centers of the cores to eliminate the possibility of contamination. Each sample was placed in a small bottle which was corked and labeled immediately. At the laboratory each bottle was sealed with paraffin, pending its preparation for microscopic study. This kept the material in a fresh, moist condition, even though it was not analyzed for several years after being brought in. No preservative was added.

The peat was prepared for pollen counts according to the alcohol method suggested by Geisler (5). For a number of samples, however, particularly from Shipshewana bog, it was necessary to modify this method somewhat. Due to low pollen frequency in the upper 20 foot-levels of this bog, a method of repeated decantation was used. This method was developed by the writer for separating pollen from river valley sediments which have an extremely low pollen frequency. For that purpose, about 20 grams of soil are used for the sample, but in applying the technique to peat, only one gram was taken. This was covered with enough alcohol to put all particles into a state of suspension when stirred. As the heavier particles began to settle out, the lighter ones, including the pollen grains, were poured off. This operation was repeated two or three times, and then the part to be used was stained with 1% aqueous gentian violet. After staining, the material was skimmed with a small pipette just above the heavier particles. These skimmings were placed on slides in the regular manner except that in many cases five or six applications were made in order to get the desired density and pollen frequency. From this point the preparation followed the regular procedure of mixing the material on the slides with warm gelatin and affixing the cover glass.

Determinations were based on Sear's (15) key, and on samples of stained pollen grains available in the Butler University laboratories. Two hundred grains were counted for each foot-level, with the exceptions of levels 5, 6, and 7 of Shipshewana bog, and 2 and 43 of Culver bog. Due to low abundance of pollen, only 100 grains were counted at these levels. The regular count included only pollen from trees. Grass pollen was also counted, but the percentages were figured on the basis of the number of grains appearing along with the 200 or 100 of the others (table I).

RESULTS

The percentages of different pollen types found in the 3 bogs are represented in figures 1 and 2. These figures include only the tree pollen, since that supplies the primary basis for deductions pertaining to forest succession. The study, however, did not disregard the possible importance of grass pollen in the deposits. In some levels of 2 of the bogs it was very abundant (table I).

All 3 bogs showed a Picea-Abies dominance in the lowest levels. In Jeff bog this dominance extended over 12 foot-levels (53-42). In the other 2 it persisted for only 3 levels (Shipshewana 39-37; Culver 43-41). Pinus was present in small percentages in all these lower levels except at the 43-foot level in Culver bog. Quercus was represented in the lowest levels except at the 53-foot level in Jeff bog (fig. 1). It superseded Pinus for a period before the end of the Picea-Abies dominance. Pinus was dominant for a relatively short period (foot-levels 36-34 in Shipshewana bog, 39-37 in Culver bog, and 41 in Jeff bog). It persisted in low percentages to the top levels.

In Culver and Shipshewana bogs it increased slightly (12-15%) near the surface.

Quercus became the dominant genus after the decline of Pinus, showing no great variations in frequency except in Jeff bog (32- to 28-foot level) and in Shipshewana (16-foot level), where it declined somewhat in favor of Larix. There was also a sharp decline of this genus at the top two foot-levels of Culver bog, due to a marked rise in Pinus and Larix.

Ulmus appeared as an early invader and persisted thereafter through all levels of the 3 bogs. It was most prominent during and immediately following the Pinus period, averaging from 12-14%. Tilia also appeared quite regularly in small amounts, but never exceeded 3.5%. Its time of invasion parallels closely that of Ulmus.

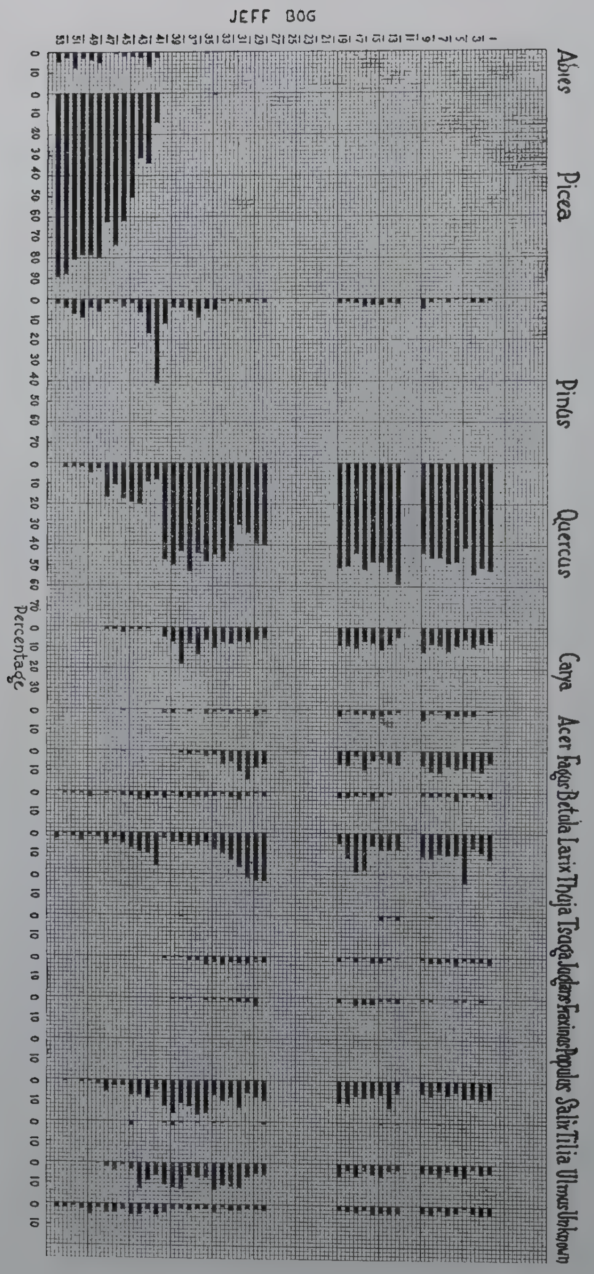
Carya made its first appearance before the close of the Picea-Abies period. It showed highest representation (17%) in the 38-foot level of Jeff bog. Considering all 3 bogs together, however, the most significant representation of Carya came in the upper 10 feet of deposition. Juglans invaded about the same time as Carya and persisted to the topmost levels. It never exceeded 4.5% and its variations in percentage showed no correlation with that of Carya.

Fagus came in surprisingly early, just after the decline of Pinus. Acer was apparently associated with it, but its representation is only in low percentages. Larix was very prominent through the greater part of the Jeff bog spectrum. It appeared consistently at all levels in the other 2, but usually only in small amounts. Culver bog is at present covered by an extensive stand of Larix associated with *Rhus vernix*.

Betula and Corylus appeared in small amounts throughout most levels in the 3 bogs. The smaller of the Betulaceae type pollen was classified as Alnus on the basis of comparison with pollen of the genus found in stream deposits studied by the writer. These were omitted from the count because of their lack of significance as indicators of successional changes. Salix showed no marked aggressive tendencies except for a few foot-levels in Jeff bog.

Fraxinus was only sparsely represented, although it appeared consistently after its invasion during the early history of the bogs. Thuja, Tsuga, and Populus were infrequent components of the spectra. Tsuga did not appear in any instance before Pinus had reached its peak.

Grass pollen was not very prominent in the Jeff bog, and showed


JEFF BOG
1
3
5
7
9
11
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17
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21
23
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27
29
31
33
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37
39
41
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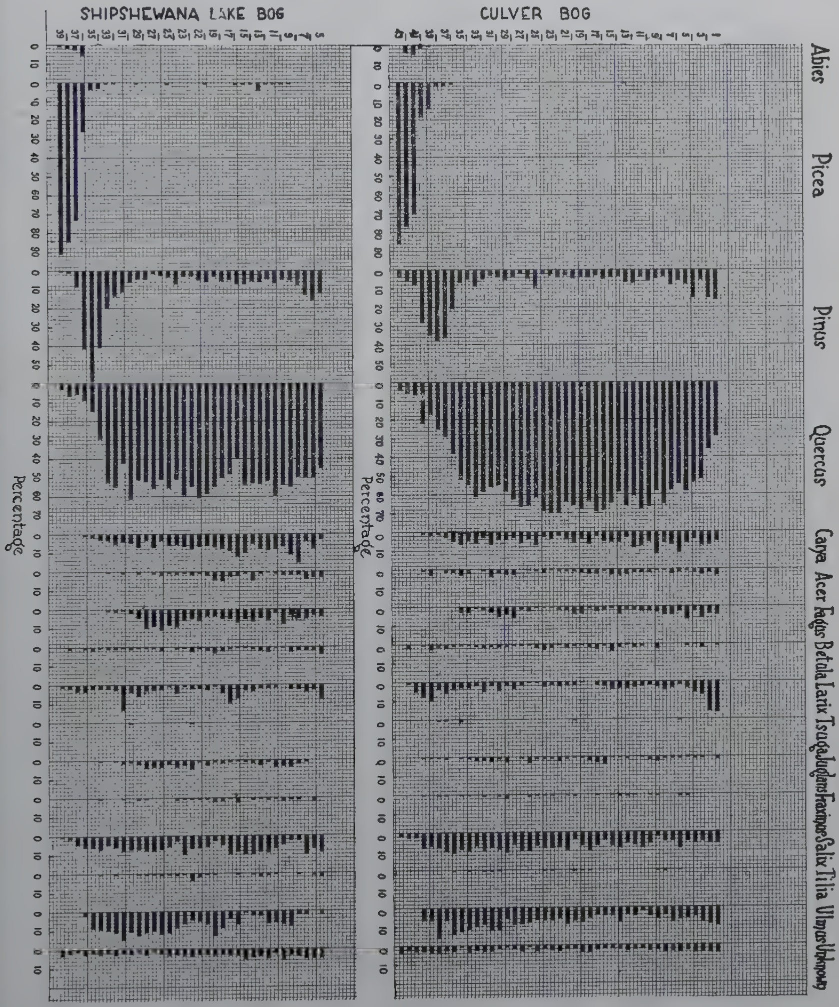
45
47
49
51
53
Abies
Picea
Pinus
Quercus
Carya
Acer
Fagus
Betula
Larix
Thuja
Tsuga
Juglans
Fraxinus
Populus
Salix
Tilia
Ulmus
Unknown
Percentage
0
10
20
30
40
50
60
70
80
90

little importance in the other 2 below the 20-foot levels. It reached a maximum representation of 43% in the 17-foot level of Shipshewana bog and 57% at the 11-foot level of Culver bog. The percentage was based on number of grains found along with 200 of tree genera. From these levels to the top it declined somewhat, maintaining an average of from 23-25% (table I).

An attempt was made definitely to identify the species of grass which contributed most of the pollen to the sediments of levels where its frequency was high, because the correct interpretation of grass



pollen in large representation is dependent on knowing whether the contributors were prairie or aquatic grasses. Fifty grains from each of the 2 levels mentioned were measured and compared with the same number of grains from each of 12 different species of grass. From the close correlation in size (table II), and also from the similarity of appearance of the pore, the grass represented at these levels was obviously *Calamagrostis canadensis*.

DISCUSSION

The study of the pollen content of successive levels of peat and marl deposits in lakes and bogs is perhaps the best available method of determining the past vegetational history of an area, yet it has many limitations, and there is the possibility of drawing unwarranted conclusions from the data derived from such sediments. We cannot say, for instance, that the different percentages of pollen found in a certain level represent the actual percentage representation of the genera constituting the forest at the time that level was laid down. Not all trees produce pollen in equal quantities, nor does all pollen distribute itself in the same manner, as is shown by Potzger (11) in his study of bogs on the Gillen Nature Reserve. Some types of pollen may be carried by wind for great distances and be deposited into a bog, while others, especially from insect-pollinated genera as Acer and Tilia, may not get into it, though originating much nearer to the bog. Another limiting factor is our lack of knowledge concerning the relative resistance of the different kinds of pollen to oxidation and other destructive forces. We know that Thuja does not preserve well when wet, but we know little about various other kinds. There is some question as to whether or not we find them in the same relative frequencies in which they were originally deposited. Also the change in appearance of certain pollen which accompanies its process of breaking down is another source of uncertainty. Some workers question whether the large structure containing a resin globule, and customarily identified as Larix, is a pollen grain or an animal cyst. If it were not included, it would make a considerable difference in some of the other percentages. It was included here, however, on the strength of certain connecting links between it and well preserved pollen.

Despite the limitations accompanying the interpretation of pollen spectra, some very definite conclusions may be drawn from them which would not be invalidated even by introduction of a wide margin of error one way or another. The spectra clearly show that the vegetation of northern Indiana immediately following Pleistocene times was of a boreal type. This may be assumed despite the presence of a small percentage of Quercus found in the bottom levels of Shipshewana and Culver bogs. Although all borings were made down to sand, it is likely that there were still several foot-levels of pollen-bearing sand below those sampled which the movable sleeve borer could not penetrate. Potzger and Wilson (14) report such conditions existing in Winona and Tippecanoe lakes, as well as for a series of lakes on the Anoka Sand Plain in Minnesota (19), showing that Quercus would have been introduced too soon and too prominently in the lower levels had not the sandy bottom been penetrated. If the marl in these bogs was produced by Chara, it is possible that sedimentation was in progress for some time before the precipitation of great amounts of calcium carbonate resulted.

Another factor not to be overlooked is that forest migration must have followed closely upon the retreat of the ice sheet, as it has been noted to do in the Arctic regions in recent times. Griggs (7) has observed that the advance of spruce along the Alaskan coast is so rapid in some places that it is evident to persons who have lived in the neighborhood only a few years. It is not definitely known to what extent Late Wisconsin glaciation caused the deciduous forests to retreat, but with the abnormally warm climate that is generally supposed to have prevailed afterward, it should not have taken these genera long, when the coniferous forest began to move northward, to follow up and regain the ground they had lost. It is also very likely that climate at the edge of the glaciers in Indiana was not influenced greatly by the ice, since it was pushed down from centers of accumulation far to the north.

The sudden breaks between the Abies-Picea and the Pinus dominance, and also between that of Pinus and the deciduous genera which are found in this and other studies, tends to indicate that the changes were almost catastrophic in nature, but considering the rapid advance possible in forest migration as noted by Griggs (7) and by Cooper (2), and comparing that with the estimate of Potzger and Friesner (14) that each foot of deposition in the lower levels of lakes and bogs represents a period of from 400 to 500 years, it would be safe to assume that the changes merely followed the natural order of succession within a normal time range, and replacement of one genus by another may be due to interference with adequate reproduction of the preceding genera, which would thus be eliminated as soon as the existing generation of trees had died. The observation of Griggs (7) and Cooper (2) pertained to factors of primary succession where the movement of trees was very rapid into previously unoccupied territory, but succession of the type shown by the pollen spectra, involving replacement of preceding forest types, would naturally be much slower than the former.

The number of foot-levels showing Pinus dominance in these bogs corresponds to those of other bogs in the Late Wisconsin area, and the percentage of Pinus pollen also corresponds well with previous studies in northern Indiana. The percentage of Pinus at the peak of its dominance was highest in Shipshewana bog, where it reached 59%. In Culver and Jeff bogs the highest points were 37.5% and 41% respectively. Potzger and Wilson (14) found 2 levels of Pinus dominance in Tippecanoe lake, with percentages of 62 and 69. In Winona lake 2 foot-levels recorded 29.5 and 40.5%. Moss (9) records 3 levels with percentages of near 40 in Loon Lake bog. Smith (17) reports from Lake Cicott the longest Pinus period shown in any of the Indiana bogs. Five-foot levels in the spectrum show between 41 and 55% Pinus pollen. The older bogs of Early Wisconsin origin lack the periods of Pinus dominance found in those of Late Wisconsin origin.

Pinus pollen is present throughout the entire spectrum, and much of that found in the upper levels resembles the pollen of *Pinus strobus*. Although Indiana is today south of the southern limit of continuous distribution of this species, it is quite likely that it was present as relic colonies about the bogs studied up to comparatively recent times, and at the Culver bog it might possibly have persisted up to the time of settlement by civilized man. Lindsey (8) described such a relic colony of *Pinus strobus* constituting the forest cover on the Merrillville bog in near-by Lake county, covering an area of approximately 9 acres. This same species is also found as relic in Pine Hills, Montgomery county, in Fountain and Warren counties as well as on the dunes about Lake Michigan. This pine and many bog species of northern range have continued in Indiana under microclimatic conditions while the center of distribution of their kind has long since moved far northward.

Fagus and Acer were early invaders, coming in to stay shortly after the peak of the Pinus period. There is no noticeable fluctuating encroachment by one or the other of these forest types commonly defined as oak-hickory and beech-maple. Apparently they occupied fringing territory of the bogs from very early times. No doubt the species of Quercus and Carya occupied south-facing slopes or other more xerophytic habitats, and Acer and Fagus associated on the more mesophytic sites, as Potzger and Friesner (13) found to be the case over a wide area in south-central Indiana. Pollen of Acer and Fagus were as consistent in distribution throughout the levels shown in the spectra as were those of Quercus species, but lower in abundance. Since the former genera, especially Acer produce less pollen than Quercus it is quite likely that the smaller pollen representation may signify much greater importance of these genera in the forest cover than the abundance figures indicate.

The order of succession shown in the three bogs was as follows:

Quercus-Carya-Acer-Fagus
↑
Quercus
↑
Picea-Pinus-Quercus
↑
Picea-Abies

It is the opinion of the writer that Larix, Salix and some other genera represented by small pollen percentages show control by microclimate or influence of edaphic factors rather than by larger successional trends. Ulmus is the only representative of the sub-dominant genera which shows any definite trend influenced by habitat change. Its consistently higher frequencies following the close of the Pinus period must have been due to wider areas of lowland occasioned by the broadened river valleys cut out by glacial drainage. This made available more suitable habitat sites for the genus.

The climatic changes indicated by the study apparently have run the following course: cold (Abies-Picea), cool moist (Abies, Picea, Pinus), warm dry (Quercus), warm moist (Quercus, Carya, Acer, Fagus). The arguments of some workers would lead one to expect evidences of a xerothermic period sometime between the decline of the Pinus period and the present. Gleason (5) places such a period immediately following the northward advance of the coniferous forest. Transeau (18) suggests that this period should be indicated by the pollen from the upper layers of peat from any bog within the limits of the Prairie Peninsula. This would involve the upper section of Indiana. Sears (16) and Draper (3) interpret the rise in percentage of grass and compositae pollen in certain levels of the New Haven, Ohio, bog as an indication of prairie invasion, extending as far east as the Erie Basin.

Jeff bog showed no evidences of such a prairie invasion. Grass pollen fluctuated little throughout, and never rose above 14% in any level. Pollen of composites was even less conspicuous. Tree pollen throughout all levels above those representing the coniferous period were also quite abundant, averaging about the same number to the slide of the mounted material. Shipshewana and Culver bogs showed a marked decline in abundance of pollen from tree genera above the 20-foot level, the number per slide being reduced to one-half or less. This, together with the sharp rise in frequency of grass pollen in the 16- to 18-foot levels of Shipshewana bog, and the 9- to 13-foot levels of Culver bog tended to indicate that the areas about these bogs had also been affected by a xerothermic period during comparatively recent times. However, evidence would have to be brought that prairie species contributed the grass pollen. Upon careful examination, measuring, and comparing various grass species, the pollen involved in these foot-levels appeared to be more like that of *Calamagrostis canadensis* than of any prairie species (table II). Most of the grass pollen from the 17-foot level of Shipshewana bog and from the 11-foot level of Culver bog measured from 27.5 to 33.7 microns in diameter, comparable in size to that of Calamagrostis. Pollen from the prairie grasses, such as the Andropogons, *Sorghastrum nutans, Agropyron smithii,* and *Bouteloua curtipendula* were consistently larger than this. The Poas and *Phragmites communis* had pollen smaller in size (table II). *Dactylis glomerata* might be considered in favorable comparison with Calamagrostis but none of the grains measured less than 30 microns.

From the camparisons shown in table II we must conclude that most of the grass pollen in these bogs was contributed by aquatic species, eliminating them as indicators of prairie invasion. The small representation of composite pollen throughout the spectra also do not point to expanding prairie influence. The only remaining feature indicating a xerothermic period is the low abundance of tree pollen in the upper levels, and it is very likely that this is due to destruction by oxidation of much of the pollen as it was deposited upon the bog mat before being added to the accumulating sediment.

SUMMARY

1. Pollen spectra are presented from Jeff, Shipshewana and Culver bogs in northern Indiana.

2. Depths of sediments in the bogs were as follows: Jeff bog 53 feet; Shipshewana bog 39 feet; Culver bog 43 feet.

3. Methods used were those described in previous Butler University pollen studies except for a modification in the technique of slide preparation which was used for samples with low pollen frequencies.

4. Forest succession indicated by the three spectra was practically the same: Picea-Abies, to Picea-Pinus-Quercus, to Quercus-Carya, to Quercus-Carya-Acer-Fagus. Pinus was more prominent during its period of dominance in Shipshewana and Culver bogs than in the more southern Jeff bog.

5. The following climatic changes are indicated by the spectra: cold (Abies-Picea), cool moist (Abies-Picea-Pinus), warm dry (Quercus-Carya), warm moist (Quercus-Carya-Acer-Fagus).

6. Grass pollen present in the bogs apparently was that of Calamagrostis, and so has no diagnostic value as an indicator of a xerothermic period in the upper part of Indiana.

ACKNOWLEDGMENTS

The writer expresses sincere appreciation to Dr. Ray C. Friesner and his assistants in the Botany Department of Butler University for collecting the peat samples; to Dr. Friesner for data on plants taken at the various bogs, and for critical reading of the manuscript. He also expresses his thanks to Dr. J. E. Potzger for supervision of the study, for helpful suggestions and reading of the manuscript, and for preparation of the profile figures. (The figures will be used by him in a larger study of forest succession in northeastern U. S.)

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TABLE I

Number of grass pollen found in Jeff, Shipshewana, and Culver bogs.

Foot-levels	Jeff bog		Shipshewana bog		Culver bog	
	No.	%	No.	%	No.	%
1	19	8.7	w	w	65	24.5
2	11	5.2	w	w	16	13.8
3	9	4.3	w	w	82	29.1
4	5	2.9	w	w	64	24.2
5	4	2.0	25	20.0	41	17.0
6	2	1.0	30	23.1	57	22.1
7	10	4.8	21	17.3	49	19.7
8	10	4.8	59	22.8	41	17.0
9	15	7.0	69	25.6	118	37.1
10	w	w	49	19.7	196	49.5
11	w	w	24	10.7	268	57.3

TABLE I—(Continued)

Number of grass pollen found in Jeff, Shipshewana, and Culver bogs.

Foot-levels	Jeff bog		Shipshewana bog		Culver bog	
	No.	%	No.	%	No.	%
12	13	6.1	63	23.9	139	41.0
13	9	4.3	57	22.1	113	36.1
14	13	6.1	56	21.9	55	21.5
15	16	7.4	81	28.9	50	20.0
16	12	5.7	125	38.5	41	17 0
17	4	2.0	153	43.3	41	17.0
18	10	4.8	113	36.1	98	32.9
19	9	4.3	23	10.3	39	16.3
20	w	w	27	11.9	32	13.8
21	w	w	26	11.5	23	10.3
22	w	w	26	11.5	21	9.5
23	w	w	20	9.1	15	7.0
24	w	w	15	7.0	15	7.0
25	w	w	15	7.0	14	6.5
26	w	w	20	9.1	12	5.7
27	w	w	24	10.7	31	13.4
28	11	5.2	15	7.0	22	9.9
29	11	5.2	14	6.5	13	6.1
30	4	2.0	15	7.0	11	5.2
31	8	3.8	12	5.7	14	6.5
32	5	2.4	11	5 2	16	7.4
33	5	2.4	13	6.1	17	7.8
34	9	4.3	12	5.7	13	6.1
35	24	10.7	13	6.1	12	5.7
36	23	10.3	14	6.5	10	4.8
37	22	9.9	16	7.4	14	6.5
38	21	9.5	7	3.3	28	12.3
39	29	12.7			22	9.9
40	23	10.3			14	6.5
41	13	6.1			10	4.8
42	16	7.4			5	2.4
43	27	11.9			2	2.0
44	32	13.8				
45	19	8.7				
46	11	5.2				
47	21	9.5				
48	5	2.4				
49	5	2.4				
50	4	2.0				
51	1	0.5				
52	1	0.5				
53	1	1.5				

TABLE II

Comparison of size ranges of grass pollen found in high frequency levels of Shipshewana and Culver bogs with those of various species of modern pollen from herbarium specimens. Measurements are given in microns.

	25 26.2	27.5 28.7	30 31.2	32.5 33.7	35 36.2	37.5 38.7	40 41.2	42.5 43.7	Above 44
Shipshewana bog 17′	8	13	14	8	5	2			
Culver bog 11′	3	12	15	11	6	3			
Calamagrostis canadensis	5	8	20	11	3	2	1		
Zizania aquatica			1	2	4	8	16	12	7
Andropogon furcatus				10	17	17	5	1	
Andropogon scoparius	1	1	1	5	12	17	11	2	
Sorghastrum nutans			1	1	8	20	20		
Agropyron smithii					4	24	9	12	1
Bouteloua curtipendula				17	21	8	3	1	
Glyceria septentrionalis				24	22	4			
Dactylis glomerata			14	20	14	2			
Poa autumnalis	19	22	8	1					
Phragmites communis	29	18	3						

TWO SOLIDAGO HYBRIDS WORTHY OF NAMES

By RAY C. FRIESNER

As a matter of taxonomic convenience it is much better to assign specific names to hybrids which are capable of perpetuating themselves indefinitely than to be under the necessity of using the cumbersome designation derived by citing the two probable parents. It would not be of material consequence, from the standpoint of taxonomic designation, whether they were ordinary hybrids which perpetuated themselves vegetatively in clones or whether they were "fixed hybrids" due to amphidiploidy.

The hybrids under consideration are two of several which have come to the writer's attention in material sent to the Butler University Herbarium for determination.

X SOLIDAGO **leiophallax** sp. nov., caulibus erectis, glaberibus praeter alte in inflorescentia, viridis vel purpurascentiis, 0.7-1 m altis; foliis basilariis absens; foliis caulinis inferioribus lanceolatis, elliptico-lanceolatis vel oblanceolatis, acuminatis, contractis in sessilem basem vel in petiolem brevem; marginis grosse serratis, dense scabris, cetera glaberibus; medianis caulinis similiis praeter grandioribus, 10-18 cm longis, 1.5-3.5 cm latis; superioribus caulinis sensim decresentia, extendens in mediis inflorescentiae; inflorescentia supra pubescentia, contracta, 4-8 cm longa, 1.5-3 cm lata, foliosa infra; capitulis nonsecundis; involucris 3-4 mm latis; phyllis exteriis lanceolatis, interiis oblongo-lanceolatis, acutis costatis, 3-4 seriatim; ligulis 6-14; floribus disci 8-13; corollae lobis 1.2-1.5 mm longis; antheribus 1.3-1.5 longis; pappo 3-3.5 mm longo; achaeniis 1.5-2 mm longis, dense pubescentibus. STEM: Erect, terete, glabrous except high in inflorescence, somewhat glaucous, green or reddish purple, 0.7-1.0 m high. BASAL LEAVES: Absent. LOWER CAULINE LEAVES: lanceolate to elliptic-lanceolate or oblanceolate; acuminate; narrowed to sessile base or very short petioled; sharply and coarsely serrate; densely scabrous on margins, otherwise glabrous. MEDIAN CAULINE LEAVES: Similar to lower except larger, 10-18 cm long, 1.5-3.5 cm wide. UPPER CAULINE LEAVES: gradually reduced in size; continuing to the middle of the inflorescence. INFLORESCENCE: pubescent in upper half; narrowly contracted 4-8 cm long, 1.5-3.0 cm wide; leafy in lower half. HEADS: nonsecund.

INVOLUCRE: 3-4 mm high. TEGULES: outer lanceolate, inner oblong to oblong-lanceolate; acute; costate; 3-4 rows. RAYS: 6-14. DISC FLOWERS: 8-13. COROLLA LOBES: 1.2-1.5 mm long. ANTHERS: 1.3-1.5 mm long. PAPPUS: 3-3.5 mm long. ACHENES: 1.5-2 mm long, densely pubescent. -ALBERTA: in open poplar woods, 0.25 mi. south of Fort Saskatchewan, Turner no. *3225, 3226* and *3255*, August 30 and September 22, 1942. Also Breitung no. *1702* and *1703*, 8 mi. south of Tisdale, Saskatchewan. Type in Butler University Herbarium; isotypes in Turner and other herbaria.

Solidago leiophallax was collected by Dr. G. H. Turner and in response to a query regarding probability of perpetuation he wrote, "from the extent of this colony I feel a confidence amounting practically to certainly that it has taken many years to reach its present proportions and that it is likely to continue and extend its range for many more years. Fortunately it is on ground owned by this town and, being preserved for recreational purposes, is likely not to be disturbed."

From the above analysis it will be seen that this hybrid is similar to *S. gigantea* var. *leiophylla* in leaf and stem characters and in general vegetative aspect and similar to *S. lepida* var. *fallax* in the nonsecund heads, the contracted inflorescence and the continuation of the leaves into the inflorescence.

Specimens collected by A. J. Breitung in open woodland, 8 miles southwest of Tisdale, Saskatchewan differ in that the inflorescence is much broader and more open and the heads are more nearly secund in the lower half of the inflorescence.

X SOLIDAGO **ulmicaesia** sp. nov., caulibus erectis, pubescentibus, viridis, 0.7-1 m altis; foliis basilariis absens; foliis caulinis inferioribus lanceolatis, acuminatis, contractis in sessilem basem vel in petiolem brevem; marginis acute serratis, scabris, supra glaberibus, infra pubescentibus; medianis caulinis similiis praeter grandioribus, 8-12 cm longis, 1.5-2.5 cm latis; superioris caulinis sensim decresentia, integris; inflorescentia late extendens, 12-25 cm longa, 10-20 cm lata; capitulis secundis praeter in supra ramis; involucris 3.5-4 mm altis; phyllis oblongis ab acutis ad obtusos, 4-5 seriatim; ligulis 3-5; floribus disci 3-5; corollae lobis 1-1.3 mm longis; antheribus 1.5-1.6 mm longis; pappo 2.6-3.0 mm longo; achaeniis 0.8-1.2 mm longis, dense minute pubescentibus.

STEM: erect, terete, pubescent, green, 0.7-1 m high. BASAL

LEAVES: absent. LOWER CAULINE LEAVES: lanceolate acuminate; narrowed to sessile base or very short petioled; margins sharply serrate, scabrous; glabrous above, pubescent below. MEDIAN CAULINE LEAVES: similar to lower except larger, 8-12 cm long, 1.5-2.5 cm wide. UPPER CAULINE LEAVES: gradually reduced in size, uppermost entire. INFLORESCENCE: pubescent, widely divergent with spreading-ascending racemes, lowermost recemes in axils of upper leaves; 12-25 cm long, 10-20 cm wide. HEADS: secund, except in uppermost branches of inflorescence. INVOLUCRE: 3.5-4 mm high. TEGULES: oblong, acutish to obtuse; 4-5 rows. RAYS: 3-5. DISC FLOWERS: 3-5. COROLLA LOBES: 1-1.3 mm long. ANTHERS: 1.5-1.6 mm long. PAPPUS: 2.6-3.0 mm long. ACHENES: 0.8-1.2 mm long, minutely pubescent.-INDIANA: in black and white oak woods on north side of Simonton lake, Elkhart county, C. C. Deam no. *56864*, September 29, 1935. Type in Butler University herbarium, isotypes in Gray Herbarium and Deam Herbarium, Indiana University.

Solidago ulmicaesia was collected by Charles C. Deam. Data on the collection label says, "In a black and white oak woods on the west bank and top of bank of a small ravine emptying into the north side of Simonton lake which is 4 miles north of Elkart. Infrequent to frequent over an area about 50 X 125 feet. Closely associated with *S. caesia* which was very common and of the large widely branching form. This species could not be found more than 50 feet from break of small hill."

Solidago ulmicaesia exhibits characters of *S. ulmifolia* and *S. caesia*. The pubescent stem and lower leaf surfaces, the widely divergent branches of the inflorescence and the secund heads are more characteristic of *S. ulmifolia*. The long, lanceolate and sharply serrate leaves, the lower inflorescence branches axillary and the nonsecund heads in the upper part of the inflorescence are more typical of *S. caesia*. The number of ray and disc flowers per head is similar in both of the supposed parents and in the hybrid. The sizes of corolla lobes, anthers, pappus and achenes of the hybrid are all closer to those of *S. caesia* than to *S. ulmifolia* as may be noted from the following measurements.

	S. caesia	*S. ulmifolia*	*S. ulmicaesia*
corolla lobes	1-1.5 mm	0.8-1 mm	1-1.3 mm
anthers	1.3-1.6	1.1-1.3	1.5-1.6
pappus	2.2-3.2	2-2.4	2.6-3
achenes	1-1.5	1.5-2	0.8-1.2

FIRST REPORTS FOR THE ALGAE BORZIA, AULOSIRA AND ASTEROCYTIS IN INDIANA

By William A. Daily

Specimens cited here are to be found in the Herbarium of Butler University, the Cryptogamic Herbarium of the Field Museum and in the personal herbarium of the writer.

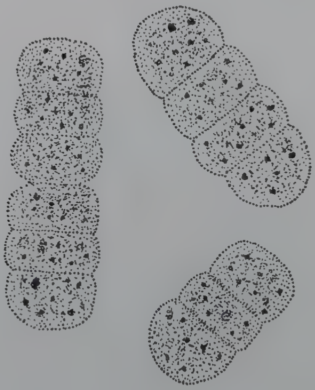
I gratefully acknowledge the suggestions and aid of Dr. Francis Drouet, Dr. C. Mervin Palmer and Fay K. Daily.

BORZIA TRILOCULARIS COHN
ex Gom., Monogr. Oscill. 118. 1893

This Myxophycean, a member of the Oscillatoriaceae, has not been reported previously for the Western Hemisphere. It closely resembles the isotypic specimen published in the Wittrock & Nordstedt, Alg. Exs. 12.587 (1883), and the description given by Gomont.

The trichomes are solitary, blue-green, without sheaths, constricted at the cross walls, and composed of from 3 to 8 cells. The cells are from 2-6 microns long, 6-7 microns wide, and the trichomes 9-20 microns long. Fig. 1.

The species associated with the specimen from Indiana are *Oscillatoria splendida* Gom. and *Gomphosphaeria aponina* Kütz. Specimens seen: Indiana: Cass County: In debris on bottom of Lake Cicott near Logansport, F. K. & W. A. Daily *1019,* Sept. 9, 1942. Sicily: Culta in aquario aquae dulcis in Breslau Germaniae anno 1883, ex



exemplaribus e Messina a.A. Borzi missis, F. Cohn leg. (Isotype of *Borzia trilocularis* Cohn in Wittr. & Nordst. Alg. exs. No. 587, in herb. of P. W. Wolle in Crypt. Herb. Field Museum).

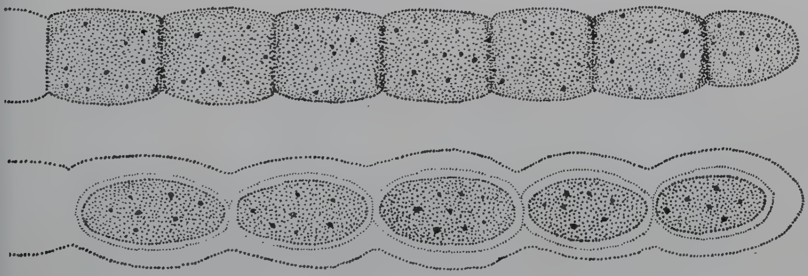
AULOSIRA IMPLEXA BORN. & FLAH.,
Ann. Sci. Nat. VII Bot. 7:257. 1888.

This genus, a member of the Scytonemataceae, heretofore has been reported for only Louisiana in North America by Prescott, Trans. Amer. Micros. Soc. 61:116 (1942), although other specimens are present in the collection at Field Museum from Quebec, South Carolina, Florida, Illinois, Texas, California, Puerto Rico, and Sonora.

Filaments straight or curved, blue-green, mostly 4-12 microns wide. Sheaths thin, colorless. Cells granular, longer or shorter than wide, 4-9 microns wide, and slightly constricted at the cross walls. Spores yellow or brown, many in a filament, 5-12 microns wide, 15-32 microns long. Fig. 2.

Plant masses float in shallow water in thin or thick gelatinous strata.

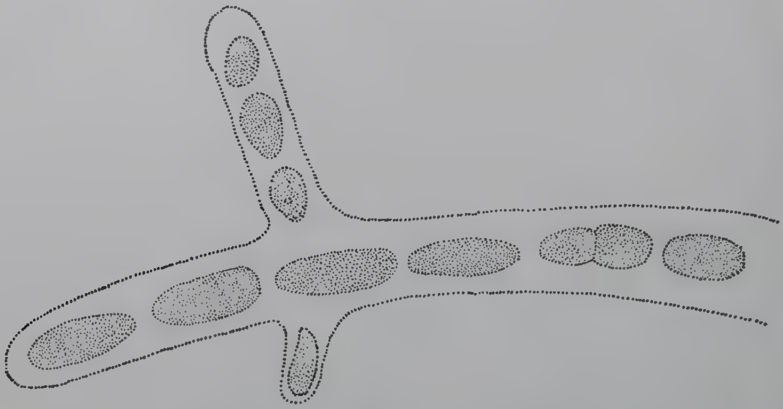
Specimens seen: Laporte County: Floating in water, Mill Creek Bog, Mill Creek, W. A. Daily *91,* July 22, 1939. Cass County: submerged in water, Lake Cicott, F. K. & W. A. Daily *1021,* Sept. 9, 1942; floating on pond on west side of State Highway 24, 4 miles west of Logansport, F. K. & W. A. Daily *1029,* Sept. 10, 1942. Lake County: floating in shallow water of Calumet River, in sand dunes north of Miller Station, Paul D. Voth & Francis Drouet *2359,* Sept. 28, 1938.



ASTEROCYTIS SMARAGDINA (REINSCH) FORTI,
Syll. Myxophyc. 691. 1907

This alga has not been reported previously for Indiana. It is yet uncertain whether Asterocytis is a member of the Myxophyceae or the Rhodophyceae.

The cells are nearly spherical to longer than wide, 4-7 microns wide and 10-14 microns long, blue-green and homogeneous. When mounted in Grams iodine a large deeply stained body irregular in outline is seen in each cell. In this body and thus in the approximate center of each cell is a small round lightly stained area. The cells are held together in uniseriate single or branched filaments by a common gelatinous matrix. Fig. 3. Specimens seen: Lake County: on Cladophora sp. on rocks in Calumet river north of Miller Station, Paul D. Voth & Francis Drouet *2366,* Sept. 28, 1938.



LEGEND FOR FIGURES

Fig. 1. *Borzia trilocularis* Cohn ex Gom.
Fig. 2. *Aulosira implexa* Born. & Flah.
  a. Vegetative filament.
  b. Filament with spores.
Fig. 3. *Asterocytis smaragdina* (Reinsch) Forti.

BUTLER UNIVERSITY BOTANICAL STUDIES

Continued from Inside Front Cover

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1. Contrasts in certain physical factors in Fagus-Acer and Quercus-Carya communities in Brown and Bartholomew counties, Indiana, by Ray C. Friesner and J. E. Potzger. Pp. 1-12. September, 1937.
2. A quantitative study of the phytoplankton of the White river canal, Indianapolis, Indiana, by Charlene Coffing. Pp. 13-31. September, 1937.
3. Fossil pollen analysis of Fox Prairie bog, Hamilton county, Indiana, by Robert L. Prettyman. Pp. 33-42. November, 1937.
4. Pollen spectrum of Lake Cicott bog, Cass county, Indiana, by William M. Smith. Pp. 43-54. November, 1937.
5. Pollen study of Cranberry pond, near Emporia, Madison county, Indiana, by Jean Barnett. Pp. 55-64. November, 1937.
6. A quantitative study of the phytoplankton of Lake Michigan collected in the vicinity of Evanston, Illinois, by William Allen Daily. Pp. 65-83. December, 1938.
7. A comparison of market milk from ten Indianapolis companies by use of the direct microscopic method of analysis, by Ina Stanley. Pp. 85-92. December, 1938.
8. Forest succession in the southern limits of Early Wisconsin glaciation as indicated by a pollen spectrum from Bacon's swamp, Marion county, Indiana, by James H. Otto. Pp. 93-116. December, 1938.
9. A fossil pollen study of Kokomo bog, Howard county, Indiana, by John W. Howell. Pp. 117-127. December, 1938.
10. A pollen profile of Otterbein bog, Warren county, Indiana, by Ruth Rebekah Richards. Pp. 128-140. December, 1938.
11. Key to species and varieties of ferns and fern allies of northeastern North American, by Ray C. Friesner. Pp. 141-162. August, 1940.
12. A phytosciological study of the herbaceous plants in two types of forests in central Indiana, by J. E. Potzger and Ray C. Friesner. Pp. 163-180. August, 1940.
13. What is climax in central Indiana? A five-mile quadrat study, by J. E. Potzger and Ray C. Friesner. Pp. 181-195. August, 1940.
14. Some necessary nomenclatorial changes in the genus Solidago, by Ray C. Friesner. P. 196. August, 1940.
15. A study of asymmetrical growth from stump sections of *Quercus velutina*, by Ray C. Friesner. Pp. 197-206. August, 1940.
16. A comparative pollen analysis of two bogs within the boundaries of the late Wisconsin glaciation in Indiana, by Byron W. Moss. Pp. 207-216. August, 1940.
17. A fossil pollen study of two northern Indiana bogs, by Frank A. Hamp. Pp. 217-225. August, 1940.
18. An observation on the effectiveness of root pressure in the ascent of sap, by Ray C. Friesner. P. 226. August, 1940.

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Filed in Stacks

BUTLER UNIVERSITY BOTANICAL STUDIES

Continued from Inside Back Cover

VOLUME V

1. A study of Lemanea in Indiana with notes on its distribution in North America, by C. Mervin Palmer. Pp. 1-26. April, 1941.
2. Quantitative study of the phytoplankton of Lake Michigan at Evanston, Illinois, by Kenneth E. Damann. Pp. 27-44. April, 1941.
3. The direct microscopic analysis of milk over a period of one year from three creameries serving Indianapolis, by George W. Wade. Pp. 45-57. April, 1941.
4. Molds found in Indianapolis markets, by Paul Lentz. Pp. 58-66. April, 1941.
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